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THE SOCIETY'S JOURNAL, called *Forestry*, is published twice a year, in June and December. It provides a means for the publication of the results of practice and research both in the growing of timber and in its utilization, including such basic sciences as forest physiology and ecology, forest soils, wood structure, and timber physics, and allied sciences such as forest entomology and forest mycology.

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SOCIETY'S MEDAL. The Council has resolved that the Society award a Medal from time to time to any individuals who may have rendered eminent services.

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NATURAL AND SEMI-NATURAL BRITISH WOODLANDS

BY A. G. TANSLEY, F.R.S.

INTRODUCTION.

THE native British woodlands have been so largely destroyed, and existing woods are now so extensively the results of planting and replanting, that foresters are naturally inclined to think of them all either as plantations or as derelict and worthless wood or scrub, of value only as possible sites for new plantation. British students of vegetation ('synecologists' as they are sometimes called), on the other hand, are interested primarily in trying to discover the nature and composition of the forests which in historical times still covered the greater part of the country, and their relation to still existing woods. The evidence they can use is of various kinds—to a certain extent historical and prehistorical records, but largely the nature and distribution of such fragments as remain of woods which are obviously native and of the still, in the aggregate, extensive 'semi-natural' woods which have been consistently exploited and sometimes partly or wholly replanted with native trees.

From consideration of such evidence a fairly complete picture of the nature and distribution of the natural forest vegetation of the country can be obtained. There are, of course, gaps in the picture, some of which can probably never be adequately filled. Certain soils have been deforested for agriculture or pasturage so completely that no trace or evidence is left of the forest vegetation that must once have covered them. Sometimes particular long continued types of exploitation have probably so altered the character of the woods that we can only guess at their original nature: a case in point is the woodland of much of the chalk plateau country of south-eastern England, where it is often hard to decide whether beech or oak was originally dominant.

But broadly speaking there is still, after 30 years of further study, no reason to doubt the essential validity of the statement made in the first general account of our natural and semi-natural woodlands.

> 'When the same association of trees occurs in wood after wood on the same type of soil, it may be concluded with reasonable certainty that we have the natural type of woodland for the given type of soil in the given climate and geographical position. It is impossible to suppose that by chance or design the whole of the woods on a given geological formation over a very considerable extent of country have been replanted with the same species other than the natural ones; especially when it is observed that on a neighbouring formation, producing a different kind of soil, quite a different type of wood is found, while in another part of the country, on a formation belonging to a different geological series, but lithologically similar and producing the same kind of soil as the first one, the same type of wood occurs as in the first case. It is this actually observed constancy in the general type of woodland over wide and often widely

separated stretches of country which leads to the conclusion that the greater part of the existing woodlands of England[1] largely retain their original character' (6, pp. 116–17. For the complete argument consult the original paper, pp. 114–18).

A good example of what is meant in the above quotation is the type of woodland regularly occurring on the chalky boulder clay of the chalk plateau in south Cambridgeshire and parts of the adjoining counties. In these woods, which are in the form of coppice-with-standards, nearly all the standard trees are oak, with occasional ash. The coppice is mainly hazel, but with abundant ash, a good deal of field maple, and a variety of calcicolous shrubs such as dogwood, wayfaring tree, and spindle. The 'field layer' also contains a conspicuous element of calcicolous herbs. On adjoining sandy glacial drift and on the greensand from which it is derived quite a different type of woodland occurs, still with oak dominant, but with much birch, no ash, few shrubs, and quite a different field layer. On deep calcareous soils in quite distant parts of the country, on the other hand, we have the same mixture of oak and ash and the same abundance of calcicolous shrubs and herbs. The chalky boulder clay woods seem to be clearly derived from this calcicolous *ash-oak wood* by exploitation as coppice-with-standards, the ash (and field maple) being generally coppiced along with the hazel and other shrubs; and they are suitably named (*ash-*)*oak-hazel wood*. Along with their presumed progenitor, the ash-oak-wood, they form a calcicolous variant of oakwood (10, pp. 272, 288–9).

If a natural wood is carefully exploited on the selection system so that it can regenerate naturally, its character will not be appreciably changed. If it is clear-felled and then replanted with the same trees it will develop again into substantially the same thing, though certain changes may be brought about in the process. Finally, if a piece of arable or grassland or moorland is planted with the trees which are naturally dominant on the particular soil a wood will be formed which, as time goes on, will approximate more and more closely to a natural wood, as it becomes gradually stocked with woodland plants—whether trees, shrubs, or herbs—whose seeds are brought by the wind, by birds, or on the boots and clothes of woodmen, shooters, and others who visit the wood. Both these two last kinds of wood may fairly be called 'semi-natural woods' though all the dominant trees have been planted. Plantations of exotic trees or of any trees which are not naturally dominant on the given soil are of course in a different category altogether.

Woodruffe-Peacock (16) gave an account of an isolated mixed plantation (nearly half the planted trees were oaks and nearly a fifth spruces) which had been made on common pasture on Kimeridge Clay in Lincolnshire at the end of the eighteenth century. Oak, ash, and wych-elm were the most successful of the planted trees, and sycamore was the only planted non-native that did well and regenerated freely. After 120 years a considerable number of genuine woodland shrubs and herbs were present, though there were a great many more

[1] Written 10 years before the establishment of the Forestry Commission, whose activities are now of course creating a larger and larger proportion of artificial woodlands.

marginal and non-woodland plants. The oaks were clearly dominant, very slow in growth and not yet reckoned as mature, though expected to yield exceedingly good timber. It might be said that after 120 years the plantation had long been a semi-natural oakwood though not ecologically mature or in equilibrium, for many plants alien to woodland were still present. A common characteristic of such plantations, even when they have become semi-natural woods, is the general absence of certain rarer woodland plants found in natural woods of the same type, whose chances of arriving from a distance are remote.

Especially in closely cultivated parts of the country, it is frequently difficult or impossible to arrive at a sound judgement on the origin of a particular wood. Records of planting are often hard to discover or non-existent, and if the original dominant has been planted on an old woodland soil there may well be no ascertainable difference between a wood so replanted and one in which the trees are the direct descendants, by natural regeneration, of those which formed an original spontaneous wood on the same site. When a plantation of the natural dominants has been made on open ground we have seen that it gradually approximates to the condition of a natural wood, though it is true that (unless the plantation is very old indeed) close investigation of the soil would probably yield decisive evidence. For the reasons given, however—in a word because of the close correlation of woodland type with subsoil type—it is legitimate to lump together all these categories as 'semi-natural woods', without reference to their actual origin. Very recent or even moderately recent plantations are of course quite easy to distinguish.

Though it is, of course, well known to foresters that nearly all trees flourish best on a deep fresh loam, it has to be recognized that within the broad climatic regions of the British Isles (which will be referred to later) there is no doubt that the main types and most of the sub-types of natural woodland are determined by soil characters. This is because particular species of tree (and the same is equally true of shrubs and herbs) can tolerate or flourish upon particular types of soil which handicap others so that they cannot make headway in competition with those which are favoured by the particular soil. It does not follow that species which fail in this way when in competition could not grow upon the particular soil in the absence of competition, nor that the actually successful dominants might not do even better on another soil. For these reasons the evidence derived from the close connexion of particular woodland types with particular types of soil must, for the purposes of forestry, be interpreted in the light of actual planting experience.

Successional stages in the development of woodland may furnish conclusive evidence of the natural status of certain woods. Thus, for example, A. S. Watt (11) found in the Goodwood region of the west Sussex Downs complete series of developmental phases between the colonization of grassland by scrub and the establishment of mature beechwood, and was thus able to trace the whole course of this succession and the natural mechanism of displacement of each phase by the succeeding one. Here we have an area which was largely

grassland in comparatively recent times, and part of which was once arable, but which has since been mainly covered by spontaneously extending beechwood. Since we now know from the evidence of pollen analysis that beech was certainly in England in prehistoric times, we may probably conclude that a nucleus of natural beechwood has been continuously present for at least three or four thousand years, and has been able to extend over open areas under favourable conditions of soil and climate when heavy grazing or arable cultivation has been withdrawn. Such examples are rare in England owing to the very thorough deforestation, widespread heavy grazing, and close cultivation of most of the country since the Middle Ages. The opportunity of so complete a demonstration as Watt's of natural forest succession is accordingly exceptional.

PREHISTORY OF WOODLAND.

The indigenous tree and shrub flora of Great Britain, even more markedly than the flora as a whole, is, of course, poor in species compared with that of equivalent parts of the Continent, and dominance of natural woodland is confined to beech, oak, ash, birch, pine, and alder. This poverty in woody plants is primarily due to the Pleistocene glaciations which in successive waves covered most of the country with ice. After these events the flora never included a number of species that could have established themselves by spreading overland from their centres of distribution. The successive glaciations were, however, separated by interglacial periods during which temperate floras existed, and the last glacial phase, in which the ice extended farthest in the west, probably permitted the survival of trees and shrubs in the south and east which were then ice-free. When the ice finally retreated fresh immigration was possible across the wide land-bridge that occupied what is now the southern part of the North Sea and the eastern Channel, but comparatively soon after the climate had substantially improved the sea invaded this bridge and cut off Great Britain from the possibility of further immigration by land. The result was that, while no doubt a number of species entered the country from the Continent after the retreat of the ice, this restocking was limited, and it may be that much of our existing flora, including some of our common trees, has survived from the last interglacial period.

The technique of pollen analysis of peats has, within the last few years, greatly increased our knowledge of the post-glacial history of forest vegetation, and though many details remain to be filled in, we are now able to present a confident and fairly complete outline picture of the course of events.

In what is called the *Preboreal period*, perhaps about 8000 B.C., after the departure of the subarctic conditions prevalent while the ice was retreating, there is evidence of climatic fluctuations. During this time birch and pine spread over the uplands—the flat lowlands must have been still very wet and supporting large meres and marshes—but oak and hazel, with some elm and alder were also present. In the succeeding *Boreal period* (say 7500 to 5500 B.C.) the climate became substantially warmer, the July temperatures being prob-

ably higher than they are now. Birch and pine were the dominant trees, but there was a great increase of hazel—very likely vast expanses of hazel scrub—its pollen in some horizons greatly exceeding that of all the trees put together. Birch, pine, and hazel penetrated to Ireland and the extreme north of Scotland. In the south the birch was on the whole the earlier dominant and pine the later, but in Scotland pine rarely equalled birch in amount. During the middle of the Boreal period oak and elm, which, as we have seen, were already present in the Preboreal, increased considerably, and though on the whole pine and birch remained dominant, the ratio of their combined pollen to that of the deciduous trees decreases. Towards the end of the Boreal period many of the southern and eastern stations show a preponderance of the pollen of deciduous trees, which included lime (*Tilia cordata*).

In the succeeding *Atlantic period* (say 5500 to 2500 B.C.) the climate remained warm but became much wetter. This period is marked by the dominance of deciduous summer forest and the great relative decrease of birch and pine, which, however, remained conspicuous in the Scottish Highlands. Among the deciduous trees the most striking change was the enormous increase in alder pollen, corresponding no doubt with the incidence of the wet climate. It is true that local dominance of alder on the edges of the fens and bogs from which the peat samples for pollen analysis are taken accounts for some of the excess of alder pollen, but the tree must also have been abundantly present throughout the oak forests of the 'hard lands'. Oak was on the whole dominant, as it is to-day, elms were apparently more abundant both in England and Ireland than they are now, and lime was very frequent at certain times and places. Of the history of the ash, a far more important member of the deciduous forest now, we know very little. Hazel, though much diminished from its Boreal superabundance, maintained itself in some quantity, probably as undergrowth of oak forest, besides forming independent scrub, as it still does in some regions. Marked growth of *Sphagnum* bogs was favoured by the high humidity of the Atlantic climate, and these invaded and destroyed some of the woods that had spread over the drying fenlands towards the close of the Boreal.

It was thus in Atlantic times that the still existing distribution of British vegetation began to take shape—deciduous forest dominated by oak (but with superabundance of alder) in England and central Scotland, more birch in the west and north, pine still strong in the Highlands.

Before the establishment of a climate similar to that which obtains at the present time, there was an interlude of—on the whole—drier conditions known as the *Sub-Boreal period* (2500 to 500 B.C.). The Atlantic forests mostly maintained themselves, but alder suffered a sharp setback, lime decreased or disappeared, while pine again invaded the drier edges of the fenlands and greatly increased in Scotland and Ireland, invading the drying bogs and in many places forming extensive pure pine forests whose stumps are exposed in countless numbers by drying and erosion of the Sub-Boreal peat. Two other trees, beech and hornbeam, spread for the first time during the Sub-Boreal

period in eastern England, and a little beech pollen has been found in these and later horizons in other parts of the country. But of the detailed history and distribution of beech and hornbeam before and after the Sub-Boreal we know, as yet, very little indeed.

The Neolithic peoples, who were the first inhabitants of Britain to keep flocks and herds and to till the soil, were present during late Atlantic and early Sub-Boreal times. Their occupation thus coincided with increasing dryness of the climate, and living as they did on the drier soils—among others the windswept crests and spurs of the chalk where forest was thin or absent—they were probably able to extend their areas of pasture and tillage over the chalk slopes as the ground became drier and less suited for tree growth (10, pp. 164–5). With the coming of metals the Bronze Age peoples, who followed the Neolithic and occupied Britain during most of the Sub-Boreal, extended pasturage and cultivation and began to push back the forests still farther, though great areas—the Weald and the Midland plain in England, for example—were still uninhabited and untouched, as shown by the absence of occupation relics, till very much later. From those times down to the present day, with continued growth of population, deforestation has steadily increased at a constantly accelerating pace.

About the middle of the millennium before Christ the climate seriously deteriorated, becoming much colder and wetter. This is the *Sub-Atlantic period*, considered by some authorities to have lasted from then till the present day. At any rate no major climatic change comparable with those which marked the passage of one major post-glacial period to the next has occurred during the last 2,500 years, though there is some evidence that the climate became temporarily drier and warmer during the Romano-British period and again about A.D. 1000. Doubtless there were similar fluctuations during earlier periods and there is evidence of some of them, but not enough is known to enable us to follow them in detail.

During the Sub-Atlantic, the old Atlantic forest, mainly dominated by oak, maintained itself, and so did much of the Sub-Boreal pine and birch forest of the Scottish Highlands, though pine disappeared from Ireland and probably from parts of western Scotland. The *Sphagnum* bogs extended again, forming the newer peats, and some have continued to grow until now, though latterly there has been much peat erosion, especially on flat summits.

THE HISTORICAL PERIOD.

During the historical period natural vegetation, and especially forest vegetation, was increasingly destroyed as the population grew (10, chap. viii). The felling of trees for timber and the cutting of underwood for firewood, tools, and numerous other purposes went hand in hand with the use of what was originally forest land for pasture and tillage. Pasturing of cattle was also extensively practised in forest and inevitably led to the death of the forest and its conversion into grassland. The proportions of arable and pasture fluctuated backwards and forwards during the centuries, but on the whole the trend has

been to increasing predominance of pasture, for which the climate is particularly well suited. In the later Middle Ages and throughout the modern period right up to the nineteenth century sheep-raising was the main rural industry on which the great wool and cloth export trades were based.

Local depletion of woodlands led to importation of timber as early as the eleventh century, and in the thirteenth and fourteenth it was brought in considerable quantity from the Baltic countries to the north-east coast, though so late as the fifteenth it was still being exported from the Weald (9, 8). During the sixteenth century there was an increasing shortage and the desirability of planting began to be spoken of. But it was not until the seventeenth century that the last reserves of the native English forests were exhausted, and England became definitely dependent on foreign supplies. Planting was then taken in hand, but quite spasmodically, and it was not till the eighteenth century that it gained a considerable impetus. In the south and centre of Scotland this sequence of events was paralleled a century earlier. From some cause which is not at all clear the dearth of timber made itself felt there at least as early as the fifteenth century and various drastic measures were taken to counteract it, though apparently with no great success (7). In the sixteenth, seventeenth, and throughout the eighteenth century extensive planting was enthusiastically undertaken (14, 7). Up to the beginning of the seventeenth century the Highland valleys, however, contained magnificent virgin forest of oak and pine. These were then 'discovered' by the exploiters and their wholesale destruction continued for more than two centuries, at first largely to obtain charcoal for iron-smelting, and later to clear the land for sheep-farming (1).

It must not be supposed that our ancestors were entirely oblivious to the importance of maintaining woodland for the supply of timber and underwood, though their efforts were unable to arrest the powerful forces at work to destroy it. Statutes and regulations were constantly enacted with the object of maintaining woodland, but they were not thoroughly enforced and many licences were granted to vested interests. The English statutes of the sixteenth century afford interesting evidence of the stabilization of the exploitation of oakwood in the form of coppice-with-standards. This doubtless took origin from the free (though not clear) felling of natural oakwood, giving increased vigour to the underwood, largely hazel, owing to the admission of more light. Thus an open canopy oakwood would be formed, consisting of trees with spreading crowns and a continuous shrub layer which would respond well to coppicing at about 10-year intervals. The standard oaks would be felled when mature and would yield good straight planks from the boles and also curved timber, particularly useful in shipbuilding, from the main branches. Regeneration of the oaks would be good in the natural woodland soil, before the enormous increase of ground vermin, consequent on the modern gamekeepers' war on carnivorous birds and mammals, led to the wholesale destruction by mice, voles, and rabbits of acorns and oak seedlings; and the young oaks would grow up into mature trees after the removal of their parents. Oak-hazel wood in

the form of coppice-with-standards could also be establis[illegible] by the planting of oak and hazel, and this form of woodland, [illegible] siderable range of soils, has thus been for centuries by far [illegible] of semi-natural wood throughout the Midlands and the sou[illegible] England, though to-day it is mainly of use for fox coverts and pheasa[illegible] serving. In some parts of the country oak itself was coppiced for firewood, largely to make charcoal for iron-smelting and glass-making, and for tanning bark, and at the beginning of the modern period those who were concerned about the supply of native timber frequently complained of the conversion of so much woodland from high forest to coppice.

THE TWO CLIMATIC FORMATIONS.

To-day Great Britain and Ireland are among the most poorly wooded countries in Europe and we have only some remaining fragments of our native woodlands from which to reconstruct their natural distribution in the country.

In the first place we must distinguish the two climatic forest formations represented in these islands: first, the *deciduous summer forest*, dominated by oak, beech, and ash, which would naturally occupy the whole of England, Wales, and Ireland, and much of Scotland, except the fen and boglands, the higher altitudes, and other situations, such as those exposed to violent winds, definitely unfavourable to tree growth; secondly, the *northern coniferous forest* dominated by pine and birch, developed in the central and northern Scottish Highlands where it interdigitates with the oakwood of the deciduous forest, the latter occupying the more sheltered situations and the better soils in the bottoms and on the lower slopes of the larger valleys and glens. It will be clear that the former is the direct descendant of the forest established in Atlantic times (with the addition of beech) and the latter of the Boreal and Sub-Boreal pine and birch forest. Geographically, at the present day, the former is a north-westward extension of the deciduous forest of western and central Europe, the latter a weak south-westward extension of the coniferous Scandinavian forest, without spruce. These two forest formations are zoned southward of the Arctic tundra in western Europe, and as the ice retreated in post-glacial times the coniferous (Boreal) forest first occupied the ground and pushed northwards, followed by the deciduous (Atlantic) forest as the climate grew warmer and moister.

DECIDUOUS SUMMER FOREST.

Oakwood (*Quercetum roboris et sessiliflorae*).

This, as we have seen, is, and always has been, mainly dominated by oak. The few associated trees, i.e. those which commonly reach the full height of the canopy, were more numerous in the primitive forest than they are in our impoverished semi-natural woods, and the Atlantic forest is known on the Continent as Quercetum mixtum. Of these trees the wych-elm (*Ulmus glabra* = *montana*) is still present and sometimes frequent, the small-leaved lime (*Tilia cordata*) is very local, and *T. platyphyllos* decidedly rare. Ash, on

the other hand, is generally frequent, though abundant (apart from planting) mainly on the wetter and on the more calcareous soils. Alder occurs in wet places and often throughout the oakwoods of the wet western climates. Hornbeam (*Carpinus betulus*), a late-comer in post-glacial times, is practically confined to south-eastern England, where it plays a subordinate part in oakwoods on silty sands and some clays. It is, however, nearly always coppiced and replaces hazel, partly or entirely, in the coppice-with-standards oakwoods of certain areas.

Of the other oakwood trees, which sometimes reach the height of the canopy, field maple (*Acer campestre*) is abundant on the better soils and is usually coppiced, the birches (*Betula pendula* and *B. alba*) can only develop in well lighted places and are often coppiced, gean (*Prunus avium*) is occasional to frequent on the better soils, aspen (*Populus tremula*), like birch, can only develop in full illumination. Of the smaller trees holly is abundant especially in damper climates, but is often cut out, crab-apple (*Pyrus malus*) is occasional to frequent, rowan (*Sorbus aucuparia*) is rare to occasional in the south-east, much commoner in the west and north, wild service (*Sorbus torminalis*) is very local, and yew (*Taxus baccata*) occasional and local.

Of the two closely allied native oaks, *Quercus robur* (*pedunculata*) and *Q. sessiliflora*, the former dominates most of the clays and loams and some of the deep sands, where it may share dominance with the sessile oak. *Q. robur* is essentially the oak of the Midlands and south-east. Also, curiously enough, Wistman's wood and two other undoubtedly natural relict woods on the acid soil of Dartmoor, where we should expect *Q. sessiliflora*, consist exclusively of *Q. robur*. It is doubtful if *Q. robur* is native in western Ireland. Elwes and Henry indeed state that all the specimens of *Q. robur* they received from Ireland were from planted trees.

Quercus sessiliflora naturally dominates the woods of the old acidic rocks of Ireland, Wales, the west and north of England, and probably of Scotland, of many of those on the acidic sands of south-eastern England, and also, it is said, of parts of the London Clay where this is acid in reaction. Wherever the two species meet hybrids are formed very freely.

The Scottish oaks are rather puzzling. Though most of the soils on which natural oakwood occurs are such as one would expect to find dominated by *Q. sessiliflora*, and this species is certainly present in quantity, yet pure typical sessile oakwood is hard to find. Most of the oaks are either aberrant forms of this species or are hybrids, and typical *Q. robur* is not at all rare. In sheltered situations on both east and west coasts north of the Caledonian Canal and on the deeper soils in the bottoms of the valleys we often have what look like surviving fragments of natural pedunculate oakwood. If the shallower soils of the lower hill-side slopes were originally dominated by some form of sessile oak, as are similar soils in the rest of the British Isles, the frequent juxtaposition of the two species may well have given rise to very numerous hybrids. It is also highly probable that the very widespread planting of oak, most likely of both species, in the eighteenth and nineteenth centuries, has greatly increased

the number of hybrids and the consequent mixture of types. In the extreme north of Caithness and Sutherland natural oak is either absent or at least extremely rare.

It is conceivable also that the greater cold of the extreme north of Scotland may have something to do with the relative success of *Q. robur* in those latitudes, for the distribution of the two species in the British Isles in relation both to climate and soil illustrates the greater tolerance of *Q. robur*, which goes farther north in Scandinavia and much farther east in Europe than *Q. sessiliflora*. The latter species is the characteristic oak of the mild and wet climates of the west and is practically confined to acid soils, whereas *Q. robur* may inhabit soils ranging from very acid to moderately alkaline.

Facies of oakwood. Five main facies of oakwood may be distinguished by their shrub and especially by their field layers, closely corresponding with soil type.

(1) *Wet facies*, with high ground water or on heavy clay, where surface water stands in winter and often late in spring, and for periods during a wet summer. Ash, alder, grey sallow, and other Salices are commonly abundant. In the field layer *Deschampsia caespitosa*, *Filipendula ulmaria*, *Urtica dioica* may be locally dominant. *Carex pendula*, *Cirsium palustre*, *Scrophularia aquatica*, and species of *Juncus* are characteristic. This facies grades into the marsh and fen woodland commonly dominated by alder.

(2) *Medium and damp facies.* This is the central type of pedunculate oakwood, formerly described as 'Damp oakwood', and developed on clays, loams, and loamy sands with good water-supply and drainage. The principal shrubs are hazel, hawthorn, and blackthorn. There is a wide range of species in the field layer according to the variety of soils on which it is developed. Some of the principal field-layer societies are dominated by dog's mercury, wood sanicle, or primrose on the heavier and better soils. Particularly on the lighter soils, but with a wide range of tolerance, we have societies of bluebell and wood anemone. *Arenaria trinervia*, *Bromus ramosus*, *Carex silvatica*, *Epilobium montanum*, *Geum urbanum*, *Geranium robertianum*, *Lathyrus montanus*, *Luzula pilosa*, *Poa nemoralis*, *Stachys officinalis* (*betonica*), *Veronica chamaedrys*, *Viola riviniana* are some characteristic species of this facies. In open canopy woods in which the shrub layer (mainly of hazel) is regularly coppiced, the flowering of the vernal gregarious species is greatly stimulated after cutting of the coppice, and brilliant shows of colour are produced by primrose, bluebell, wood anemone, and later by red campion (*Melandrium dioicum*) or yellow archangel (*Galeobdolon luteum*). *Catharinea undulata* and *Thuidium tamariscinum* are the commonest dominants of the moss layer; but there are many other species.

Facies (1) and (2) are most characteristic of Quercetum roboris, but are also represented on damp fertile shales in Quercetum sessiliflorae.

(3) *Calcicolous facies.* Where there is abundant lime in the soil, ash is always prominent; wych-elm, *Betula pendula*, and yew are often abundant; and several species of calcicolous shrubs—much more abundant in southern England than in the north, and generally rare in or absent from Scotland—such as dogwood, spindle, wayfaring tree, common buckthorn, sometimes with elder

and privet, are a conspicuous feature. The field layer is often dominated by mercury and contains calcicolous herbs such as *Campanula trachelium*, *Clinopodium vulgare*, *Hypericum hirsutum*, *Paris quadrifolia*, *Viola hirta*, *V. silvestris*. This type of oakwood ('ash-oakwood', see p. 2) is confined to Quercetum roboris and is transitional to calcicolous ashwood.

(4) *Facies of drier and more acid soils.* This facies, formerly described as 'dry oakwood', is characteristic of sandy, but not podsolized soil, and the lighter soils on the old rocks, and occurs in both sessile and pedunculate oakwoods. The shrub layer is much poorer than in facies (2) and (3), and where hazel coppice exists it has probably always been planted. The bracken fern is a common and widespread dominant, particularly in open woods. It is often associated with *Holcus mollis* and/or *Scilla non-scripta*, or alternatively with bramble, and honeysuckle is often abundant. Other common species of the field layer are *Conopodium majus*, *Galium saxatile*, *Hypericum pulchrum*, *Potentilla erecta*, *Teucrium scorodonia*, *Viola riviniana*, and in open places and clearings foxglove or rose-bay willow-herb. *Dicranum scoparium* and *Polytrichum formosum* usually occur in the moss layer.

(5) *Heathy oakwood.* This is characteristic of the most podsolized and acidic soils and is much commoner in Quercetum sessiliflorae. But it is also the characteristic type on the deep sands of the south-east of England where both species of oak occur. Birch (*B. pendula* and/or *B. pubescens*) are characteristic accompanying trees, and also *Sorbus aucuparia*, especially in the north. In the heathy woods of the south-east beech and pine are also frequent. Shrubs are rare: holly is frequent and *Frangula alnus* is characteristic of damper sites. The field layer is very often dominated by bracken or by bilberry (*Vaccinium myrtillus*). *Calluna* is common in open places and *Deschampsia flexuosa* is the most characteristic grass, but *Holcus mollis* and *Agrostis tenuis* are often present. In the heathy sessile oakwoods of the wet western climates *Luzula maxima* is often locally dominant, and the bryophytes increase both in species and individuals. Species of *Dicranum* and *Hylocomium* are abundant, and such oxyphilous mosses as *Dicranella heteromalla*, *Hypnum schreberi*, and the liverwort *Diplophyllum albicans*. The heathy facies shows transitions to pinewood and birchwood.

Beechwood (*Fagetum silvaticae*).

The beech (*Fagus silvatica*), as we have seen, entered, or at least spread in, the country not much earlier than the Sub-Boreal period, i.e. later than any other of our indigenous trees except hornbeam. At the present day it is most perfectly at home, regenerating freely and forming natural woods only in the south and mainly the south-east of England. Nevertheless, it can regenerate well on suitable soils as far north as Aberdeenshire, where it was planted in the eighteenth century. In southern England its main foci are round the western and northern sides of the Weald, on the two sides of the middle Thames valley, extending north-eastward along the Chiltern Hills, and on the Cotswold Hills of Gloucestershire. The first two of these are on the Chalk, the third

on the Oolites. There are also two or three outlying areas in South Wales on Carboniferous (Mountain) Limestone and Old Red Sandstone. On the Chalk, to the south-west of the first two areas, i.e. in Wiltshire and Dorset, there is no undoubtedly natural beechwood, and the same is true of the continuation of the main chalk escarpment north-east of the Chilterns, i.e. in Cambridgeshire and Norfolk, though there are plenty of beech plantations. The preliminary results of pollen analysis, however, make it probable that beech was once much more widely spread than now, and that the scattered beech occurring in Wales and south-west England may well be descendants of native trees. How far north it went is still quite uncertain.

The types of natural beechwood are various and quite well characterized:

(1) *Calcicolous beechwood* (*Fagetum calcicolum*). This is developed on shallow highly calcareous and richly humous soils such as occur on the steeper chalk slopes of the escarpments and valley sides, and also on the Inferior Oolite escarpment and valley sides of the Cotswold Hills. These woods are very nearly pure beech with an occasional ash and an occasional whitebeam (*Sorbus aria*) reaching the height of the canopy (60 or 70 feet). Shrubs are rare, but there is sometimes a more or less dense understory of yew, and holly is frequent. The field layer varies very much in development. In young dense woods the ground is almost entirely bare, the shade being very deep and the shallow surface soil very thoroughly exploited by the roots of the young trees so that it may become very dry in the summer. As the canopy opens out herbaceous plants begin to colonize the floor of the wood, and in an older wood there may be a continuous field layer rich in species. This is commonly dominated on the chalk (the Cotswold woods have not been closely investigated) by wood sanicle (*Sanicula europea*) on the shallower, and by dog's mercury (*Mercurialis perennis*) on the deeper soils. Of the abundant species sweet woodruff (*Asperula odorata*) and the early-flowering wood violet (*Viola silvestris*) are very characteristic, and so is *Viola hirta*. *Fragaria vesca*, *Galeobdolon luteum*, *Anemone nemorosa*, *Circaea lutetiana*, all of which are also common in oakwoods of facies (2) may be locally dominant, and *Arum maculatum* and *Euphorbia amygdaloides* very frequent. These are all spring flowering plants, vegetating largely in the 'light phase', i.e. before the beech foliage is fully developed. Other characteristic species are *Daphne laureola*, a dwarf evergreen shrub particularly abundant in the Cotswold beechwoods, *Helleborus viridis* var. *occidentalis*, *Lactuca muralis*, *Melica uniflora*, *Aquilegia vulgaris*. But perhaps the most characteristic of all are the orchids *Epipactis latifolia* and especially *Cephalanthera grandiflora*, practically exclusive to and remarkably constant in calcicolous beechwood, the rare *C. ensifolia*, and the colourless saprophytic *Neottia nidus avis*, with its fellow saprophyte *Monotropa hypopitys*, which is allied to the heaths. These all grow only where the humus is deep.

Mosses are largely confined to the upper surfaces of the large spreading roots, the bases of the beech trunks, and the ground immediately around, but the whole number of species, especially in the sanicle woods, where there is more space between the herbs, is very large. *Hypnum cupressiforme* on the bases of

the beech trunks and roots, and *H. molluscum* (calcicolous) on the soil, are the most abundant, but there are many o hers as well as some liverworts. Of the larger fungi, which are very abundant in favourable seasons, *Collybia radicata*, *Hygrophilus eburneus*, *Mycena pelianthina*, *M. pura*, and *Cortinarius calochrous*, the last named apparently exclusive to calcicolous beechwood, are among the most characteristic.

(2) *Brown earth beechwoods* (*Fagetum rubosum*), mainly on the plateau of the chalk. These are on much deeper soils (loams) than those of the steep chalk slopes. The soil sometimes contains free calcium carbonate, but on the Chiltern plateau the loam is markedly acid and quite free from lime, though rich in exchangeable calcium. Here the trees show the greatest height growth, which may exceed 100 feet. Many of the woods are practically pure beech, but oak (*Quercus robur*), which is absent from the escarpment woods, is occasional to locally abundant and reaches a height equal to that of the beech, with which it is then co-dominant. Ash is present and reaches the height of the canopy, and subspontaneous sycamore is locally dominant or co-dominant with beech on the plateau of the western South Downs, recalling the beech-maple forest of the eastern United States. Wild cherry (*Prunus avium*) is locally frequent in the Chiltern plateau woods and may reach the height of the canopy. Yew and holly are sometimes present, especially in the more maritime climate of the South Downs which favours their evergreen habit.

A distinctive feature of the mature plateau woods is the field layer of bramble which may interfere with beech regeneration. In an earlier stage of development, and also in the deeper shade, wood sorrel (*Oxalis acetosella*) may be dominant. The other species of the field layer are very numerous, but the individuals are usually scattered. They include characteristic 'exacting' species of the calcicolous woods, such as dog's mercury, sanicle, sweet woodruff, wild strawberry, yellow archangel, doubtless because of the fertile soil rich in exchangeable calcium. The tall wood grasses *Festuca gigantea*, *Elymus europaeus*, and *Milium effusum*, as well as the oakwood grass *Bromus ramosus*, are common in the beechwoods of the Chiltern plateau, and the acid soil also supports such species as bracken, foxglove, *Agrostis tenuis*, and *Holcus mollis*. Species of moss are much fewer than in the calcicolus woods, largely because the dense field layer of bramble does not allow them space to settle. Of the larger fungi *Collybia butyracea*, *C. platyphylla*, *Laccaria laccata* and var. *amethystina*, *Mycena galopus*, *M. sanguinolenta*, *Russula atropurpurea* and *R. cyanoxantha* are characteristic.

In natural succession the plateau beechwoods on loams are preceded by ash-oakwood, followed on the deeper and more acid soils by oakwood, which is gradually invaded and suppressed by the climax beechwood. On the heavier loams and clays of the 'clay-with-flints' covering the chalk plateau, oak competes on equal or more than equal terms with beech, and on these soils there are woods of co-dominant oak and beech as well as many semi-natural oak-hazel woods of the old standard type from which beech may be entirely absent. From some of these pure oakwoods, beech may have been

cut out because of the old demand for oak timber. It is certainly true that many woods of these types have been planted, but for the reasons given on pp. 1–4 it is legitimate to regard the whole of this series of woods as semi-natural, especially since their natural successional relations have been carefully worked out by Watt (1924, 1925) on convincing evidence, though the varying methods of exploitation are of course an important factor in their existing form.

(3) *Beechwood on sands and podsols* (*Fagetum ericetosum*). Covering much of the plateau and dipslope of the Chiltern chalk are a variety of silty and sandy soils which are more or less podsolized and extremely acid, with a thick surface litter passing down into a compact raw humus (*mor*). Much of this area is occupied by beechwood of which the height growth is poor (60 feet or less) and the stems often crooked. Oaks accompany the beeches, which they often exceed in height, and holly is the commonest accompanying shrub. The ground is often bare and in the sparse local field layer the more exacting herbs are absent, and oxyphilous species—*Calluna*, *Carex pilulifera*, *Deschampsia flexuosa*, *Hypericum pulchrum*, with *Hypnum schreberi*, *Leucobryum glaucum*, *Diplophyllum albicans*, &c.—are characteristic.

A similar type of beechwood occurs on many of the south-eastern sands (parts of Epping Forest, Burnham Beeches, and many small woods south of London) which are often podsolized. Of accompanying trees and shrubs *Quercus robur* and/or *Q. sessiliflora*, *Betula alba*, *B. pubescens*, and *Sorbus aucuparia* are characteristic, with holly, juniper, and *Frangula alnus*. Ash, field maple, and hazel are quite absent. Honeysuckle is the characteristic climber and ivy is absent. The field layer is absent from considerable areas. In some of these woods bilberry is dominant, and often bracken where the shade is not too deep. *Holcus mollis* or *Deschampsia flexuosa* are locally dominant, and *Melampyrum pratense* is abundant in some places, with other oxyphilous species. Of bryophytes the species already mentioned occur, with *Leucobryum* often forming large conspicuous cushions and sometimes almost the only plant under the beeches. Of the larger fungi *Amanita mappa*, *Amanitopsis fulva*, *Paxillus involutus*, *Russula* spp., *Scleroderma aurantium*, and a number of others are characteristic.

The natural succession from sandy heath leads through birch and oak to beech, though it is doubtful if beechwood is a permanent climax on these soils owing to the difficulty of regeneration on the smooth surface *mor*.

Somewhat similar but subspontaneous beechwoods with bilberry (blaeberry) dominant in the field layer have been described by Watt (1931) from Aberdeenshire.

Calcicolous ashwood (*Fraxinetum calcicolum*).

The fact that British limestone soils (outside the present beechwood area) are occupied by native ashwood was first clearly pointed out by Moss (1907, 1913), who described them on the Mountain Limestone of Somerset and Derbyshire. Observations in other parts of the country have since shown that wherever natural or semi-natural woodland occurs on calcareous soil directly

derived from limestone or from markedly basic igneous rocks, and in the absence of beech, it is dominated by ash. Most of these woods are situated on steep hill-sides, on scree formed from limestone cliffs above, and the soil is typically shallow and very highly calcareous, so that oak is excluded just as it is from the beechwoods of the steep chalk escarpments. Only where the soil is deeper and less calcareous can oak find a footing. Since ash casts a much lighter shade than oak the shrub layer, or alternatively the field layer, is often densely developed.

Wych-elm is the most frequent and characteristic tree, field maple and aspen rather characteristic, and also, especially in the south, whitebeam and yew, while bird cherry (*Prunus padus*) is frequent in the northern ashwoods. Birch is usually absent except at the higher altitudes. The commonest shrubs are hazel and hawthorn, which are abundant everywhere. The calcicolous shrubs (dogwood, spindle, buckthorn, privet, elder, and wayfaring tree) are characteristic, but several are rarer in or absent from the northern limestone woods.

Of field-layer communities Moss (1907, 1913) described a characteristic society of *Allium ursinum* on damp, and of *Mercurialis perennis* on drier, soil. In the driest places on scree incompletely colonized by woody plants, there are societies of *Nepeta hederacea*, *Hypericum hirsutum* (calcicolous), *Teucrium scorodonia*, and locally of stone bramble (*Rubus saxatilis*) and lily of the valley (*Convallaria majalis*)—both usually calcicolous. A considerable number of species occur in the limestone ashwoods which are quite absent from oakwoods in the same district. Among these are *Convallaria majalis*, *Geranium lucidum*, *G. sanguineum*, *Hypericum hirsutum*, *H. montanum*, *Polemonium caeruleum* (south-western), *Phyllitis scolopendrium*, *Rubia peregrina* (mainly south-western), *Rubus saxatilis*, *Viola hirta*, *V. silvestris*. The rare baneberry (*Actaea spicata*) seems confined to a few of these woods.

In the north of England and in Wales some of the calcicolous ashwoods occur at fairly high altitudes, and the ash and wych-elm are here accompanied by birch (*Betula pubescens*) and also sessile oak. At the highest levels ash disappears and birch alone, accompanied by rowan, remains. The climatic effect thus causes a convergence of type in the highest altitude woods on both calcareous and siliceous soils (cf. p. 20).

On deeper calcareous soils oak (*Q. robur*) is associated with ash. This type of wood (ash-oakwood) has been referred to on pp. 2 and 11.

In succession limestone screes, such as form below the steep cliffs and crags ('scars') of the Mountain Limestone, for example in the Craven district of west Yorkshire, are colonized by hazel and hawthorn which form loose thickets into which yew, whitebeam, and ash enter, and from these the typical calcicolous ashwood takes origin. It also forms on the flat fissured limestone pavements characteristic of the same and other regions. The fissures are colonized by many species of woodland plants before woody vegetation becomes dominant. Hawthorn, hazel, and ash grow up from the fissures and so a wood is gradually established, the flat horizontal surfaces of the pavement between the fissures becoming eventually covered with humus and vegetation.

Alderwood (*Alnetum glutinosae*).

During the Atlantic period there must have been very large alderwoods throughout the country bordering the extensive lakes and meres, and occupying wide stretches of marsh and fen. With the shrinking of these in a drier climate the alderwoods diminished, but much survived into historical times, and increasing clearance and drainage for cultivation have now restricted alderwood to comparatively small marsh and fenwoods, and to narrow belts along the sides of streams and ponds. The natural habitat of alder is well humous soil with a fairly good supply of nutrient salts. It avoids very acid peat bogs, though belts of alder are often developed along the 'laggs' or marginal drainage streams of raised bog where the water is richer in electrolytes. The tree can of course flourish in well-drained soil provided the water-supply is adequate, and it is frequent in the hill-side oakwoods of our wetter western climates.

Alderwood on wet alluvial mineral soils has never been properly investigated, but some of the fenwoods ('carrs') of the 'Broads' region of east Norfolk on typical fen peat afford one of the rare British examples of practically virgin woodland. Alder is dominant in many, though not in all, of these carrs, which may remain dominated by tall shrubs (*Salix atrocinerea*, *Rhamnus catharticus* or locally *Viburnum opulus*). Ash and birch (*B. pubescens*) are the commonest associated trees. Oak (*Q. robur*) occurs in some of the woods and with increased drying and consolidation of the peat there is probably succession to wet oakwood. Besides the shrubs mentioned, *Frangula alnus*, and, less abundantly, hawthorn and the calcicolous privet and spindle may be present on fen peat rich in lime. Red and black currant and gooseberry are characteristic. Of climbers the hop (*Humulus lupulus*), greater bindweed (*Calystegia sepium*), and bittersweet (*Solanum dulcamara*) may be abundant.

In the field layer stinging nettle (*Urtica dioica*) is often locally dominant. Other prominent and abundant species are *Caltha palustris*, *Carex paniculata*, with its great stools, *C. acutiformis*, *Filipendula ulmaria*, and *Iris pseudacorus* (which do not flower under the shade of carr), *Dryopteris thelypteris*, *Eupatorium cannabinum*, *Galium aparine*, and *G. palustre*, *Lycopus europaeus*, *Lysimachia vulgaris*, *Lythrum salicaria*. Many of these also occur in fen with no tree or shrub cover, and there flower more freely.

The air of carr is constantly very moist, and there is a corresponding abundance of bryophytes and lichens on the tree-trunks and branches, on the masses of fallen branches and twigs, and sometimes even covering the young growing shoots. Few of the species are particularly characteristic of alderwoods.

In the valley—fenwoods of Breckland poplars (*Populus canescens*, *P. nigra*) and species of willow (*Salix alba*, *fragilis*, *purpurea*, *triandra*, and *viminalis*) are associated with alder. Birch (especially *B. pubescens*) is often found with alder in the carrs, and may be locally dominant, forming nearly pure birch carr. In succession the carr itself is often formed on floating tussocks of peat (swamp carr) with open water between. With the entrance of birch the peat becomes

consolidated, paving the way for the final establishment of oakwood. At Sweat Mere in Shropshire a complete hydrosere has been traced from the open water of the mere through *Typha* and *Carex paniculata* swamp and *Salix atrocinerea* thicket to alderwood, and thence to birch and oakwood, though the later stages may have been partly determined by drainage.

NORTHERN CONIFEROUS FOREST.

The remaining fragments of pine and birchwood in the central and northern Highlands are, as we have seen, descendants of the old Boreal forests which covered most of Britain eight or nine thousand years ago, receded in the Atlantic period, and received a fresh impetus in Sub-Boreal times four thousand years ago. The requirements of the dominants are closely similar and they are generally found together on the same soils. Birch succumbs to pine in direct competition, but maintains itself better, though it makes very poor growth, under generally adverse conditions of soil or climate.

These woods contain very few species of associated trees and shrubs, and their field layers are generally heathy.

Pinewood (*Pinetum silvestris*).

A comparison of some of the remaining areas of native pinewood show that they are mainly developed on glacial sands and gravels, often strongly podsolized. For the most part they are remarkably pure, the only associated trees, which are few in individuals, and unable to compete with pine, being birch and rowan, with a little aspen and alder. Shrubs, other than the heaths and juniper, are absent.

The field layer is often dominated by *Calluna* in open woods, and, when the pine is in close stands, by *Vaccinium myrtillus* and *V. vitis-idaea*. Associated plants are very few owing to the overwhelming dominance of the heaths and mosses. The commonest are *Blechnum spicant* and *Deschampsia flexuosa*, with a few other species. There is a well marked, almost continuous ground layer dominated by luxuriant mosses, usually with *Hylocomium splendens* and *H. triquetrum* (sometimes *H. loreum*) leading: other frequent mosses are *Hypnum crista-castrensis*, *H. schreberi*, and *Dicranum* spp. *Sphagnum* spp. (e.g. *S. cymbifolium*, *girgensohnii*, and *plumulosum*) are also abundant in the wetter climates, not necessarily on wet soil

In the eastern Highlands (Rothiemurchus Forest) pine forest reaches an altitude of more than 2,000 feet, the highest existing forest limit in the British Isles, though towards its upper edge it is very open, with many windfalls and many crippled and dead trees. The field layer maintains its general type, but with crowberry (*Empetrum nigrum*) and bearberry (*Arctostaphylos uva-ursi*) frequent or abundant. According to White (1898) *Corallorhiza trifida*, *Goodyera repens*, *Moneses grandiflora*, *Linnaea borealis*, *Listera cordata*, *Pyrola media*, *rotundifolia*, *secunda* and *minor*, and *Trientalis europaea* are specially characteristic of old native pine forest, the first three being confined to it and all being more or less rare (some exceedingly rare) except the last two.

In most places in the Highlands pine now shows almost complete failure to regenerate owing to the ubiquity of grazing (deer or rabbits). Where this factor is absent or negligible, as in parts of Rothiemurchus Forest and near Loch Maree, there is very good regeneration.

Southern subspontaneous pinewoods. There is no doubt that, apart from the old Scottish pinewoods, the common pines are nowhere so much at home as they are on the Cretaceous, Eocene, glacial, and post-glacial sands and gravels in south-eastern England. Their spread from planted pine and from mature subspontaneous pinewoods over sandy commons and heaths is extraordinarily free, and close stands of pine are produced with great rapidity owing to very quick growth from about the 4th to the 12th year. The shade of middle-aged pinewood kills out most of the heaths (e.g. *Calluna*, *Erica*) and the ground becomes thickly covered with pine-needle litter underlain by raw humus and a thin layer of structureless peat. Under these conditions there are no shrubs and no field layer, though a few suppressed flat-topped plants of oak, beech, or sweet chestnut often occur. Here and there bilberry and silver hair-grass are met with, and *Molinia* can also maintain itself though it does not flower. There are a few oxyphilous mosses, *Leucobryum*, *Hypnum schreberi*, *Campylopus flexuosus*, *Dicranum scoparium*, &c., as well as lichens belonging to the genus *Cladonia* where light is sufficient. But the most abundant vegetation consists of fungi, which are very numerous in a favourable season and include *Amanita rubescens*, species of *Boletus* and *Russula*, *Paxillus involutus*, &c.

These southern subspontaneous pinewoods are seldom allowed to become very old, so that it is uncertain whether they would open out, develop a good field layer, and regenerate *in situ*, or give way to another type of wood. Subspontaneous pines often spring up in the middle of open oak-birchwoods on heathy ground, but they do not compete successfully with the oaks.

Birchwood (*Betuletum pendulae et pubescentis*).

Birchwoods are still not at all uncommon on the sides of Highland glens even in the far north, though the trees are generally badly grown, often badly attacked by disease, and many obviously moribund. Their number and extent are known to have greatly decreased even in quite recent times, and this seems to have been formerly due to the widespread sheep-grazing and more recently to the deer from the overstocked 'deer forests' which injure the trees and prevent regeneration by browsing on saplings and seedlings. The birches of the north of Scotland have hitherto been considered as forms of *Betula pubescens*, but they are now thought to represent an as yet undescribed species.

By far the commonest accompanying tree is rowan, a few individuals of which are rarely absent from a birchwood. In the Caithness birchwoods described by Crampton (1911) alder, forming local societies in the wettest places, aspen, and bird cherry are the only other trees recorded, while of shrubs there are only hazel and sallows (especially *Salix aurita*). It is interesting to note that birch, rowan, aspen, and bird cherry are the deciduous trees which reach the highest altitudes in the coniferous forest zone of the Alps.

The field layer is sometimes dominated by bracken, sometimes by bilberry (*Vaccinium myrtillus*) and grasses, of which *Anthoxanthum*, *Deschampsia flexuosa*, and *Holcus mollis* are abundant. It also contains a number of herbs of which only *Galium saxatile*, *Potentilla erecta*, and *Viola riviniana* are at all abundant, with *Listera cordata* and *Trientalis europaea* characteristic species that the Highland birchwoods share with the pinewoods. The remaining species are widespread woodland plants able to tolerate the more or less extreme conditions. There are a few ferns, of which *Blechnum spicant* (apart from bracken) is the commonest, and various mosses. In the wetter places the more tolerant marsh plants are found, with species of *Sphagnum*. Nearly all the species may occur in oakwood of various types. A very few, such as *Ajuga pyramidalis*, *Listera cordata*, and *Trientalis europaea*, are characteristically northern in distribution. Thus these northern woods are for the most part, though not entirely, negatively rather than positively characterized.

Farther south, in the eastern Highlands, there are woods of *Betula pendula*. One of these had a shrub layer of juniper, able to endure the very light shade of the birches in open canopy, and a rabbit-grazed turf consisting largely of *Deschampsia flexuosa* with several heath and woodland species, and the usual dominant Highland mosses.

In contrast with the Highland pinewoods, the birchwoods are largely on the finer-grained and somewhat better soils of hill-sides, where grasses play a larger part in the vegetation. Such woods are much more grazed than the pinewoods on glacial morainic material where the heathy field layer offers little to the grazing animal. But the vegetational differences are not sharply marked and most of the species are common to both types, with the addition in the birchwoods of a selection of tolerant oakwood species.

Altitudinal limits of woodland. The general pasturing of sheep on the hill-sides, together with the more recent ravages of deer in the Scottish Highlands, has greatly depressed the upper limits of forest throughout northern Britain, besides rendering the great majority of English, Welsh, and Scottish hills, bare of trees even on their lower slopes. But an underlying cause, antecedent to human agency, of the general restriction and depression of the upland woods is probably the increased wetness and coolness of the summer climate during the Sub-Atlantic period, i.e. during the last 2,500 years. Such a climate not only favours the spread of the wet moorland plants, notably *Sphagnum*, *Scirpus caespitosus*, and *Eriophorum*, which are the enemies of forest, but also independently checks the establishment and growth of young trees. Brockmann-Jerosch (1919) showed that the highest forest limits occur in the most continental regions of the Alps and in those which contain the largest and highest mountain masses. The highest existing forest limits in Britain are in the most 'continental' parts of the Scottish Highlands, which also contain the largest high mountain mass, the Cairngorm Mountains. Thus the south-westward extension in Britain of the Scandinavian Northern Coniferous Forest is depressed, both latitudinally and altitudinally in our western oceanic climate.

The oakwoods which still exist, though now largely replaced by planted conifers, in the valleys of the Highlands usually have a fringe of birchwood or birch and pinewood along their upper edges, and this is also true of some of the oak and ashwoods of northern England. These 'subalpine' woods correspond with the latitudinal zone of birch in the extreme north. Peat pollen records, as well as the numerous birch and pine stumps in the upland mosses of the Highlands and also of the Pennines show that these upland woods were once much more extensive and reached much higher altitudes than now.

Seral birchwoods. Besides dominating the climax birchwoods described above, birches are conspicuous in the oakwood succession on the lighter soils, particularly the sands, throughout Britain. In the valleys of the central and southern Highlands the birches, and especially *B. pubescens*, are abundant in all kinds of situations and are constant constituents of the more open oakwoods. A depleted oakwood constantly 'fills up' with birch, and areas of moorland or grassland protected from excessive grazing may quickly be colonized by birch seedlings from parent trees in the neighbourhood. Within the oakwood region a birchwood so produced would naturally be followed by oak colonization resulting in the establishment of climax oakwood, though under existing conditions this rarely happens.

In the south of England the establishment of these small seral birchwoods is very frequent indeed. Here also the birches, both *B. pubescens* and *B. pendula*, are constant associates of the oaks, especially on sandy soils; and they colonize the open heathland characteristic of these soils very freely. Oaks come more slowly both because they form less seed and because the seed is less mobile, but in smaller numbers they can often be seen accompanying and following the birches. Human interference, however, nearly always occurs sooner or later and we have to be content with observing fragments only of the natural succession.

The relation of oak and birch in Britain is a good illustration of the principle that the dominant of a 'pre-climax' forest is also the climax dominant of an adjacent, less favourable, climatic region which excludes the climax dominant of the more favourable region. The same relation holds between beech and ash on limestone soils.

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'WITCHES' BROOMS' ON THE CRICKET-BAT AND OTHER WILLOWS

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THE so-called 'witches' brooms' observed commonly on various species of willows in Britain are attributed to the gall mite, *Eriophyes triradiatus* Nalepa, which was originally described from central Europe by Nalepa in 1892 (3). The species is referred to by the same author in 1894 (4) and again (5) in greater detail in a revision of the gall mites affecting willows. Nalepa records the gall as occurring on *Salix fragilis* L., *S. alba* L., and *S. babylonica* L.

The gall consists usually of a distortion of the female flower buds which develop abnormally. The reproductive organs become hypertrophied and this is accompanied by an enlargement of the floral bracts and the development of adventitious buds at their bases. This results in the typical 'witches' broom' gall. The gall mite is apparently only found when the gall is in its incipient stage and, as far as the writer is aware, the mite itself has not been observed in Britain.

Christy (2) records that 'witches' brooms' on willows were first noted in Britain when Chittenden (1) exhibited to the Royal Horticultural Society on 9 October 1906 specimens collected at Buckhurst Hill, Essex. Christy suggests that Epping Forest was the probable district in which the gall first appeared about 1906. He states that the gall characteristically makes a sudden appearance in great abundance on all the willows in a district, and that in 1915 it was probably present in most localities in the metropolitan area within a few miles of London, and might be more widely distributed, as additional localities were Castle Hedingham, Essex, and Stroud, Glos. (1911). In view of this, Warburton (6) is in error when he reports 'witches' brooms' on willows attributed to *E. triradiatus* as occurring for the first time in England near Cambridge in 1928.

Christy, in residing near Chelmsford, which is the centre of the bat willow-growing industry, was well aware of the difference between the cricket-bat willow, *S. alba* var. *caerulea* Smith, and other willows. This is shown by his use of the correct technical terms applied to these willows by the industry as well as their scientific names. He reports that the galls are usually found on *S. fragilis* ('open-bark', 'crack', or 'wrong sort' willow), which seems to be most affected, and clearly states that it is certain that they have not yet been observed on *S. alba* var. *caerulea* ('close-bark' or 'cricket-bat' willow), and hopes that this species will remain immune. It appears, therefore, that this gall has not been recorded hitherto on the bat willow.

With a view to finding the species of willow most affected by 'witches' brooms' a survey was undertaken from January to April 1937. No foliage is present on the trees at this time of the year and galls are then much more conspicuous. The galls observed were produced in 1936 or in previous years, as galls certainly persist on the trees for more than one year. Observations were made while the writer was investigating the insect fauna of the bat willow in an attempt to find the insects most likely to be responsible for the transmission of the 'watermark' disease of this tree. Such observations were practically restricted of necessity to those parts of south-eastern England in which the bat willow is chiefly grown. It was, however, found possible to include some observations in the Midlands and the north of England. The survey actually extended to twelve counties, and, while far from comprehensive, serves to show the widespread distribution of the gall, the species of willow most affected, and the severity of the attack.

The appearance of trees with few or no galls is strikingly different from those with many, and it was thought that no useful purpose would be served by making actual counts of the number of galls. The localities where observations were made, the species of willow involved and the severity of attack, as indicated by the abundance of galls, are given in Table I. Under abundance of 'witches' brooms' the following terms are used with these arbitrary meanings: 'none' = a complete absence of galls, 'few' = an occasional one or two to an average of two or three galls per tree, and 'many' = an average of about 10 to 100 or more galls per tree. Observations were almost invariably made of a number of trees in each locality, so that the term used gives a reasonably accurate picture of the severity of the attack.

TABLE I. *Abundance of 'witches' brooms' on various species of willows in twelve counties*

Locality	*Host willow*	*Abundance of 'witches' brooms'*
Chelmsford, Essex	*S. fragilis*	many
Writtle, Essex	*S. caerulea*	none
Danbury, Essex	*S. caerulea*	few
Great Easton, Essex	*S. caerulea*	few
	×*S. viridis*	many
Harlow, Essex	*S. caerulea*	none
	S. fragilis	many
Quendon, Essex	*S. caerulea*	few
	S. fragilis	many
Bishop's Stortford, Herts.	*S. caerulea*	few
	S. fragilis	many
Braughing, Herts.	*S. caerulea*	none
Cambridge, Cambs.	*S. caerulea*	many
	S. fragilis	many
	×*S. viridis*	many
	S. babylonica	few
Grantchester, Cambs.	*S. caerulea*	many
Great Shelford, Cambs.	*S. fragilis*	many

Locality	*Host willow*	*Abundance of 'witches' brooms'*
Ickleton, Cambs.	*S. caerulea*	none
Stapleford, Cambs.	*S. caerulea*	none
	S. fragilis	many
Duxford, Cambs.	*S. fragilis*	few
Fenstanton, Hunts.	*S. alba*	few
	×*S. viridis*	few
Abbotsley, Hunts.	*S. alba*	none
Brampton, Hunts.	*S. alba*	none
	×*S. viridis*	none
Spaldwick, Hunts.	*S. alba*	none
Oakham, Rutland	*S. fragilis*	none
	×*S. viridis*	none
Langham, Rutland	*S. fragilis*	many
Melton Mowbray, Leics.	*S. fragilis*	many
Wymeswold, Leics.	*S. fragilis*	many
Cavendish Bridge, Leics.	*S. fragilis*	many
Kegworth, Leics.	*S. fragilis*	many
Tansor, Northants.	*S. caerulea*	none
Burton Latimer, Northants.	*S. fragilis*	many
Warkton, Northants.	*S. fragilis*	many
Weekley, Northants.	*S. caerulea*	none
Barton Seagrave, Northants.	*S. fragilis*	many
Uttoxeter, Staffs.	*S. alba*	none
	S. fragilis	none
Rudyard, Staffs.	*S. fragilis*	none
Bentley, Staffs.	*S. fragilis*	none
Rempstone, Notts.	*S. fragilis*	many
Derby, Derby	*S. fragilis*	none
Shardlow, Derby	*S. fragilis*	many
	S. triandra	none
	S. purpurea	none
	S. viminalis	none
Brailsford, Derby	*S. fragilis*	none
Kirk Langley, Derby	*S. fragilis*	few
Hilton, Derby	*S. fragilis*	few
Macclesfield, Ches.	*S. fragilis*	none
Bollington, Ches.	*S. fragilis*	none
Wilmslow, Ches.	*S. fragilis*	none
	S. purpurea	none
Alderley Edge, Ches.	*S. fragilis*	few
Prestbury, Ches.	*S. fragilis*	none
Woodford, Ches.	*S. fragilis*	none
Bramhall, Ches.	*S. fragilis*	none
	S. caprea	none
Stokesley, Yorks.	*S. fragilis*	few

It will be seen that 'witches' brooms' were much more abundant in south-eastern England and the Midlands than farther north. Except for one locality (Shardlow), few or no galls were found in Staffordshire, Derbyshire, and Cheshire, although numerous observations were made. In Cheshire, for example, where willows were examined in seven localities, no galls were found

except for a few on three trees of *S. fragilis* at Alderley Edge. 'Witches' brooms' doubtless occur in many other parts of these counties, but it is without question that they are more abundant in the south than in the north. Among factors limiting the distribution are probably to be included the less favourable climate and the relative scarcity of willows in the north.

'Witches' brooms' were found on the following willows: *Salix fragilis* L., ×*S. viridis* Fries., *S. alba* L., *S. alba* var. *caerulea* Smith, and *S. babylonica* L. They were never observed on *S. triandra* L., *S. purpurea* L., *S. viminalis* L., and *S. caprea* L. *S. fragilis* was more often affected by the gall and, when it was attacked, to a greater degree than any other species of willow. The hybrid ×*S. viridis* is a cross between *S. fragilis* and *S. alba*, and is especially common in the Fens. As regards the severity of attack, it is interesting to note that ×*S. viridis* seemed to occupy a position intermediate between *S. fragilis* and *S. alba*, which is what would be expected from a cross between these species. *S. alba* appeared to be attacked least of all, but few observations were made on this species. *S. alba* var. *caerulea* was affected to a relatively slight extent, two cases only being observed where the attack was severe, but even these did not approach the severity of many of the heavy attacks on *S. fragilis*.

In eight south-eastern and midland counties, where the incidence of galls was high enough to enable comparisons to be made between the species of willows, a striking difference was seen between the severity of attack on *S. fragilis* and other willows. This is shown in Table II. This difference was particularly noticeable in *S. fragilis* and *S. alba* var. *caerulea*. Thus *S. fragilis* was severely attacked in 15 (88·2 per cent.) of the localities and only slightly or not at all in 2 (11·8 per cent.). *S. alba* var. *caerulea*, on the other hand, was severely attacked in only 2 (16·7 per cent.) of the localities and slightly or not at all in 10 (83·3 per cent.). These results are expressed with some reluctance as percentages in view of the small number of observations.

TABLE II. *Number of localities in eight counties where attacks of 'witches' brooms' were severe, slight, or absent*

Host willow	*Number of localities*	
	Severe attack	*Slight or no attack*
S. fragilis	15 (88·2%)	2 (11·8%)
S. alba var. *caerulea* . . .	2 (16·7%)	10 (83·3%)
×*S. viridis*	2	3
S. alba	0	4

'Witches' brooms' caused by mites or more rarely fungi are well known on many trees, but in most cases no very appreciable injury results unless the attack is especially severe. 'Witches' brooms' strikingly similar in appearance to those caused by *E. triradiatus* on willows have been commonly observed by the writer on cacao trees (*Theobroma cacao* L.) in Trinidad, B.W.I. These

galls, which consist of remarkably hypertrophied shoots, are caused by the fungus, *Marasmius perniciosus* Stahel. This so-called 'witch-broom' disease first appeared in Trinidad in 1928, where it now ranks as the most important disease of cacao, although the main damage results from the infection of the cacao pods by the fungus rather than the production of 'witches' brooms'.

As regards the 'witches' brooms' on willows, there seems to be little doubt that the injury to the trees is of negligible extent. Large trees of *S. fragilis* are probably little affected by the presence of the galls, but young trees appear to be checked in their growth when heavily attacked, as has been occasionally observed. As far as the writer is aware, this is the first record of the occurrence of 'witches' brooms' on *S. alba* var. *caerulea* (cricket-bat willow). It is reassuring for growers of this willow to learn that this species is only rarely heavily attacked, and even when this is the case, little or no appreciable damage to the tree results. At the present time 'witches' brooms' cannot be regarded as a serious pest of the bat willow.

SUMMARY.

1. 'Witches' brooms', attributed to the gall mite, *Eriophyes triradiatus* Nalepa, were found more abundantly on willows in south-eastern England and the Midlands than farther north.

2. They were found on *Salix fragilis* L., ×*S. viridis* Fries., *S. alba* L., *S. alba* var. *caerulea* Smith, and *S. babylonica* L., but were never observed on *S. triandra* L., *S. purpurea* L., *S. viminalis* L., and *S. caprea* L.

3. *S. fragilis* was more often attacked and usually much more severely than any other willow.

4. 'Witches' brooms' are recorded apparently for the first time on *S. alba* var. *caerulea* (cricket-bat willow).

5. The cricket-bat willow is only rarely heavily attacked, and, as 'witches' brooms' cause little or no appreciable damage to the tree, they cannot be regarded as a serious pest.

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EXPERIMENTS IN GREAT BRITAIN WITH WOOD PRESERVATIVES FOR THE PREVENTION OF *LYCTUS* ATTACK

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INTRODUCTION.

THE need for an effective preservative treatment for the protection of hardwoods from attack by *Lyctus* Powder-post beetles has been evident ever since losses due to these insects assumed serious proportions in Great Britain during the years following the war of 1914–18. Early investigations (8) into the economic importance of *Lyctus* in this country indicated that the bulk of such losses resulted from the importation of seasoned timber already infested, and that in comparison attack originating in home-grown hardwoods was negligible. The urgency of the problem demanded in the first place a method of reducing the large amount of *Lyctus* infection present in oak, ash, and other susceptible hardwoods entering this country and stored at docks, timber yards, and similar places. For this purpose a successful heat sterilization treatment was evolved as a result of experiments in the U.S.A. and Great Britain (18, 7, 13). Such a treatment, however, is only a temporary cure and prevents neither initial attack nor the possibility of reinfestation after treatment.

It was, therefore, with the object of finding a suitable preservative treatment which could be applied to seasoned timber immediately after heat sterilization that a considerable amount of experimental work has been done at the Forest Products Research Laboratory at Princes Risborough. Apart from this main object, however, the work also formed part of a project for determining the relative toxicity of wood preservatives to wood-boring insects generally. Until recently it was possible to use only *Lyctus* for this more extensive investigation and the experiments here described have, therefore, included tests with substances which would not necessarily be suitable for the prevention of *Lyctus* attack under commercial conditions.

PREVIOUS WORK.

Although general recommendations for the prevention of *Lyctus* damage by chemical methods had already been made by Altson (1), Munro (11), and others in Great Britain, by Snyder (17) in the U.S.A., and by Roughley and Welch (16) in Australia, details of any experimental work on the subject were not available until 1936, when Cummins and Wilson (6) published an account of their investigations in Australia. In 1939 Cummins (5) gave an account of further experiments and later in the same year Christian (3) reported on the

results of tests in the U.S.A. The economic aspect of the work in all three countries has recently been reviewed by Cann (2).

TYPES OF PRESERVATIVE.

The most important properties which wood preservatives for general purposes should possess have been enumerated by several workers, including Richardson (15), who has classified them into three types, 'oil', 'water-soluble', and 'solvent'. Coal-tar creosote is the best known and most widely used preservative of the oil type; its permanence and other advantages, however, are for the present purpose offset by the stain produced, and although there are on the market several refined creosote products which cause only slight discoloration of the timber, it is not possible to paint or otherwise finish successfully wood which has been treated with a preservative of this description. The water-soluble type is represented by metallic salts such as zinc chloride, sodium fluoride, &c., which are used extensively for the general preservation of timber not in contact with the ground; many preservatives of this type are colourless and cheap, and are, therefore, useful where absence of stain and low cost are important advantages. The solvent type of preservative consists of a toxic chemical dissolved in a volatile oil or spirit solvent, which after treatment evaporates and leaves the toxic chemical in the wood. On the whole these preservatives penetrate wood slightly better than the other types and are thus more suitable for superficial treatments of timber. They are, however, considerably more expensive, and most of the common solvents are highly inflammable.

Of these three types, water-soluble preservatives appeared particularly suitable for the purpose of preventing *Lyctus* attack, and experimental work at Princes Risborough has therefore been largely concerned with these.

MATERIALS.

1. *Insects.*

Lyctus brunneus Stephens has been used throughout the tests. The beetles were not standardized in any way, but were obtained when available and as required from infested timber stored in the Laboratory's insectaries, either by hand collecting or from light traps.

2. *Timber.*

Oak sapwood was used throughout these tests and except for one experiment where unseasoned timber with a moisture content of 62 per cent. was used, it was seasoned beforehand to a moisture content of 12–15 per cent. Early work was handicapped by lack of knowledge of the feeding habits of *Lyctus* larvae. The result was that the absence of attack in treated wood samples which had been exposed to *Lyctus* beetles was at first attributed to the efficacy of the treatment, but may in some instances have been due to a deficiency of starch, the presence of which is now known to be essential for the development of

Lyctus larvae. As soon as the importance of starch was realized (14, 19), all timber to be used in these experiments was examined beforehand for its presence by means of the iodine-potassium iodide test.

Two sizes of wood sample were used:

(*a*) Large samples (6×4×1 in.) containing a minimum of 50 per cent. sapwood (in the more recent tests these samples were reduced in width to 6×2×1 in.).

(*b*) Small samples (3×1×½ in.) composed entirely of sapwood.

3. *Preservatives.*

A list of the preservatives tested will be found in the table of results, and it is intended here merely to comment on some of the substances used.

Of the water-soluble preservatives, potassium chromate was tested at the request of the Research Department, Woolwich, who claimed that this chemical had been used successfully for the protection from *Lyctus* attack of hardwoods at the Arsenal timber stores. Amongst those of the oil type, orthodichlorbenzene has been suggested (1, 17) as suitable for the protection of timber stored in closed sheds, and mixtures of creosote and paraffin have been recommended in Australia (4) for general use out of doors. Paraffin and turpentine have long been advocated for use against wood-boring insects generally and a series of low-temperature tar phenols was tested at the request of the Chemical Research Laboratory, Teddington, to ascertain their toxicity to such insects. Several proprietary preparations of the solvent type, containing such substances as metallic naphthenates, were tested in order to provide information on their comparative toxicity. Seekay wax (R. 93), a chlorinated naphthalene wax, was also included in the tests: field tests (10) with a wax of this type in different parts of the world have shown it to be one of the most effective preservatives for use against termites.

METHODS.

1. *Treatment of Timber.*

The tests described have been undertaken over a long period and different methods of treatment have been investigated. In the first instance, the test samples were impregnated under pressure by the 'full cell' process with different concentrations of water-soluble preservatives, in order to ascertain the minimum concentrations lethal to *Lyctus* larvae. The majority of the samples were, however, treated by superficial applications of unheated solutions by brush, spray, or short-period immersion treatments.

All samples were weighed immediately before and after treatment and the amount of preservative absorbed was determined. In the case of water-soluble preservatives, the absorption was expressed in grammes of dry salt per square centimetre of wood surface or per cubic centimetre of wood, according to whether the preservative was applied superficially or by impregnation treatment. The absorptions of oil and solvent type preservatives, which were applied by superficial treatments only, varied considerably in individual

samples, and it has only been possible to give average figures per cubic centimetre of wood for certain preservatives.

In addition, some tests were undertaken at Princes Risborough by Yarrow and Harris (20) with zinc chloride to determine whether the penetration of water-soluble preservatives into seasoned oak sapwood could be increased by the following methods:

(*a*) By adding a wetting agent to decrease the surface tension of the preservative solution.

(*b*) By heating wood samples at a temperature of 130° F. for 30 minutes prior to immersion for different periods in a cold solution, with and without the addition of a wetting agent. The extent of penetration of the zinc chloride was determined by applying a standard chemical reagent to the chiselled surfaces of the treated wood samples, according to the method described by Hunt and Garratt (9).

2. *Exposure of Wood Samples to Insects.*

Wood samples treated with water-soluble preservatives were, as a rule, exposed to *Lyctus* beetles within a few weeks of treatment, but in the case of oil and solvent preservatives the interval was usually longer, and in some instances sets of samples were kept for a year or more after treatment before exposure to beetles. The larger samples were exposed to beetles in breeding cages made of copper gauze with a wooden framework and the smaller ones in tins with a covering of muslin. In order that beetles might have access to all surfaces for egg-laying the samples were raised on small sticks of softwood. The tests were carried out at laboratory temperature and humidity.

One set of wood samples consisting of three large and five small samples were used for each test. In addition, one set of untreated control samples was included for each series of preservatives tested at the same time. In most of the tests control samples were exposed separately, but in some instances they were also exposed along with treated samples. The number of beetles used in the experiments was as follows:

10 males and 10 females for each large sample.
3 males and 3 females for each small sample.

3. *Examination of Samples.*

(*a*) *Small Samples* ($3 \times 1 \times \frac{1}{2}$ in.). In order to observe larval development and the progress of attack, if any, portions of these samples were cut off periodically after exposure to beetles and examined in detail under a binocular microscope by shaving away thin sections of the wood with a razor. Examinations were made in this way for eggs and living or dead larvae and the results recorded at each examination.

(*b*) *Large Samples* ($6 \times 4 \times 1$ in.). As a rule these samples were left unexamined for six months or more after exposure to *Lyctus* attack. They were then inspected superficially by planing the surfaces to expose living or dead larvae and later for the presence or absence of beetle exit-holes.

Untreated control samples of both sizes were examined in a similar manner. Observations were made by these methods for approximately nine to twelve months, when the tests were concluded.

RESULTS.

A condensed summary of the results of the tests with each preservative is given in the following tables in which the value of the different preparations for the prevention of *Lyctus* attack is recorded by their classification into two categories:

(*a*) 'EFFECTIVE', signifying that the treatment did not necessarily prevent *Lyctus* beetles from egg-laying but that the extent of tunnelling produced by newly hatched larvae before dying was negligible.

(*b*) 'INEFFECTIVE', signifying that the treatment did not prevent appreciable larval damage.

The results of some of the earlier tests, where the starch content of the wood was doubtfully adequate, are not included.

Water-Soluble Preservatives

BORAX

1. *Impregnation treatment* (*full cell*).
   - 0·1 per cent. (0·0006 gm. salt per c.c. of wood) . . . . . Ineffective
   - 0·5 per cent. (0·003 gm. salt per c.c. of wood) . . . . . EFFECTIVE
   - 1·0 per cent. (0·006 gm. salt per c.c. of wood) . . . . . EFFECTIVE
   - 3·0 per cent. (0·02 gm. salt per c.c. of wood) . . . . . EFFECTIVE
   - 5·0 per cent. (0·03 gm. salt per c.c. of wood) . . . . . EFFECTIVE
2. *Immersion treatment* (*30 sec.*) *immediately after heating wood samples at 130° F. for 30 min. with and without wetting agent.*
   - 5·0 per cent. (0·0004 gm. salt per sq. cm. of wood) . . . . . Ineffective
3. *Immersion treatment* (*30 sec. or 5 min.*) *in unheated solution.*
   - 5·0 per cent. (0·0006 gm. salt per sq. cm. of wood) . . . . . Ineffective
4. *Immersion treatment of unseasoned timber* (*moisture content 62 per cent.*) *in unheated solution* (*10 sec.*).
   - 5·0 per cent. (Absorption figure for unseasoned timber obtainable by analysis only.) . . . . . Ineffective

POTASSIUM CHROMATE

1. *Spraying* (one application).
   - 5·0 per cent. (0·0005 gm. salt per sq. cm. of wood) . . . . . Ineffective
2. *Spraying* (two applications).
   - 5·0 per cent. (0·0004 gm. salt per sq. cm. of wood) . . . . . Ineffective

3. *Spraying* (one, two, and three applications).
   5·0 per cent. . . . . Effective*
   (0·0015 gm. salt per sq. cm. of wood per application)
4. *Immersion treatments (5 min. to 24 hours) in unheated solutions.*
   5·0 per cent. . . . . Ineffective
   (0·0003 to 0·006 gm. salt per sq. cm. of wood)

SODIUM CHLORIDE

1. *Immersion treatment of 30 sec. in unheated solution.*
   5·0 per cent. . . . . Ineffective

SODIUM FLUORIDE

1. *Impregnation treatment (full cell).*
   0·1 per cent. . . . . Effective
   (0·0006 gm. salt per c.c. of wood)
   0·5 per cent. . . . . Effective
   (0·003 gm. salt per c.c. of wood)
   1·0 per cent. . . . . Effective
   (0·006 gm. salt per c.c. of wood)
   3·0 per cent. . . . . Effective
   (0·02 gm. salt per c.c. of wood)
2. *Immersion treatment (30 sec.) immediately after heating wood samples at 130° F. for 30 min. with and without wetting agent.*
   3·0 per cent. . . . . Ineffective
   (0·0003 gm. salt per sq. cm. of wood)
3. *Immersion treatment (30 sec. or 5 min.) in unheated solution.*
   3·0 per cent. . . . . Ineffective
   (0·0003 gm. salt per sq. cm. of wood)

SODIUM FLUOSILICATE

1. *Immersion treatment (30 sec. or 5 min.) in unheated solution.*
   5·0 per cent. . . . . Ineffective
   (0·0006 gm. salt per sq. cm. of wood)

ZINC CHLORIDE

1. *Impregnation treatment (full cell).*
   0·1 per cent. . . . . Ineffective
   (0·0006 gm. salt per c.c. of wood)
   0·5 per cent. . . . . Ineffective
   (0·003 gm. salt per c.c. of wood)
   1·0 per cent. . . . . Ineffective
   (0·006 gm. salt per c.c. of wood)
   3·0 per cent. . . . . Effective
   (0·02 gm. salt per c.c. of wood)
   5·0 per cent. . . . . Effective
   (0·03 gm. salt per c.c. of wood)

* Treatment given by Research Department, Woolwich. No appreciable damage recorded in any sample, but in view of results from further tests with samples treated at Princes Risborough this treatment cannot be considered effective.

2. *Immersion treatment of 30 sec. immediately after heating wood samples at 130° F. for 30 min. with and without addition of a wetting agent.*
   5·0 per cent. . . . . Ineffective
   (0·0007 gm. salt per sq. cm. of wood)
3. *Immersion treatment (30 sec. or 5 min.) in unheated solution.*
   5·0 per cent. . . . . Ineffective
   (0·0006 gm. salt per sq. cm. of wood)

Oil Preservatives

Preservative.	*Treatment.*	*Interval between Treatment and Exposure to* Lyctus.	*Results.*
Creosote 1 part Paraffin 9 parts	Immersion for 30 sec. in unheated mixture	2 months	Ineffective
Creosote 1 part Paraffin 4 parts	,, ,,	2–3 months	Effective*
Creosote 1 part Paraffin 2 parts †	Immersion for 5 min. in unheated mixture	11 months	Effective
Paraffin	Immersion for 10 sec. in unheated preservative	20 months	Ineffective
Turpentine	,, ,,	,,	Ineffective
Paraffin 50 parts Turpentine 50 parts	,, ,,	,,	Ineffective
Phenols (Low-temperature tar)			
(*a*) B.P. 180°–200° F.	One brush treatment	13 months	Effective
(*b*) B.P. 200°–220° F.	,, ,,	,,	Effective
(*c*) B.P. 80°–120° F.	,, ,,	,,	Effective
(*d*) B.P. 120°–150° F.	,, ,,	,,	Effective
Orthodichlorbenzene	,, ,,	,,	Effective
	Immersion for 10 sec. in unheated preservative	1 month	Effective

* Attack recorded in only one sample out of eight, but starch inadequate in majority.
† Absorption of creosote and paraffin mixture varied from 0·026 to 0·083 gm. per c.c. of wood.

Solvent Preservatives

Preservative.	*Treatment.*	*Interval between Treatment and Exposure to* Lyctus.	*Results.*
Seekay Wax (R. 93)* (20% in benzene)	Immersion for 5 min. in unheated preservative	2 months	Effective
,, ,,	,, ,,	9 months	Effective
Benzene (Control)	,, ,,	2 months	Ineffective

* Absorption of Seekay Wax varied from 0·006 to 0·017 gm. wax per c.c. of wood.

DISCUSSION AND CONCLUSIONS.

From these results it is evident that the water-soluble preservatives tested were effective in preventing *Lyctus* attack only when applied by an impregnation

treatment. The most toxic substances were sodium fluoride and borax, which prevented any significant *Lyctus* damage at concentrations as low as 0·1 and 0·5 per cent. respectively, and it is of interest to note that the lowest effective concentration of zinc chloride was found to be 3 per cent. These results agree generally with those of Cummins and Wilson (6) in Australia, who used the sapwood of *Eucalyptus obliqua* throughout their tests. They found, however, that zinc chloride was effective at a concentration of 0·8 per cent. and that sodium fluosilicate, which was not included amongst the impregnation treatments at Princes Risborough, was even more toxic than sodium fluoride or borax, giving complete protection at a concentration as low as 0·05 per cent. These workers point out that an impregnation treatment overcomes all the disadvantages of a superficial treatment which can only be temporary. It is contended, however, that the expense of the former method is likely to restrict its use in practice. Moreover, complete impregnation is not essential in order to render susceptible timber free from *Lyctus*. The beetles insert their eggs into the exposed pores or vessels of the wood at a depth which, according to Parkin (12), does not exceed 6 to 7 mm. in the case of *Lyctus brunneus*. It is probably necessary, therefore, for the preservative to penetrate only to this depth in order to kill young larvae when they commence feeding. It is realized that a successful treatment applied by this superficial method will only prevent attack until the timber is re-sawn, when new untreated surfaces will be exposed to *Lyctus* infestation. Experience has shown, however, that the bulk of infection takes place during or after seasoning and before wood is dressed or re-sawn.

The failure of these preservatives to prevent damage when applied at much higher concentrations by short immersion treatments showed that penetration was insufficient by this means, and that *Lyctus* eggs laid in the pores of sapwood so treated were likely to be outside the zone of treated timber. Moreover, neither heating the wood immediately before immersion nor the addition of a wetting agent to the preservative solution increased the penetration sufficiently to prevent *Lyctus* attack.

No more effective results were obtained by immersing unseasoned oak with a moisture content of 62 per cent. for 10 seconds in an unheated 5 per cent. aqueous solution of borax, but Christian (3) claims that attack by *Lyctus parallelopipedus* can be prevented by immersing green oak for the same period in a 2½ per cent. solution of this preservative at a temperature of 130° F. He found, however, that the method failed to prevent attack by *Lyctus planicollis* and suggests as a reason that the latter may lay its eggs deeper within the pores than the smaller species *L. parallelopipedus*.

It will be noticed that the tests undertaken with potassium chromate involved longer immersion treatments than with the other water-soluble salts. The reason was that the Research Department, Woolwich, with whose cooperation the tests with this preservative were undertaken, claimed that a spraying treatment under commercial conditions with a 5 per cent. aqueous solution effectively prevented *Lyctus* attack. Similar spraying treatments

applied to experimental samples of oak at Woolwich effectively prevented any significant *Lyctus* damage when the samples were subsequently exposed to attack at Princes Risborough, but infestation was recorded in a further series of samples treated in the same way and exposed to attack at the Laboratory.

It was suggested by authorities at Woolwich that the failure of the treatment on a small scale might be due to an insufficient quantity of potassium chromate being deposited on the samples with the result that small quantities of the salt might be rendered ineffective by reduction. Further tests involving prolonged immersion treatments were therefore undertaken at Princes Risborough in which the amount of salt deposited per sq. cm. of wood was greater than that obtained at Woolwich. These samples, however, were subsequently infested by *Lyctus*.

In contrast to the failure of water-soluble preservatives, many of the oil type proved effective when applied by means of immersion treatments varying from 10 seconds to 5 minutes. Whilst paraffin and turpentine were found to be of no value, orthodichlorbenzene and four fractions of low-temperature tar phenols were effective. Creosote mixed with two parts by volume of paraffin also prevented *Lyctus* attack, but an increase in the proportion of paraffin to reduce the stain of creosote reduced also the toxicity of the mixture. Many preservatives of the solvent type also proved effective, including a chlorinated naphthalene wax (Seekay Wax R. 93), and a number of proprietary preparations containing such substances as metallic naphthenates.

In conclusion, it is apparent that surface applications of cold solutions of water-soluble salts by spraying or dipping treatments are of no value for the protection of seasoned timber following heat sterilization treatment, nor for the prevention of *Lyctus* attack during air drying. Nevertheless, water-soluble preservatives, of which borax and sodium fluoride have given the best results, when applied by impregnation treatments (full cell or hot and cold processes) are effective and, where facilities exist for their application, provide a simple means of rendering sapwood immune from *Lyctus* infestation. The use of one of these substances, namely boric acid, has recently been adopted on a commercial scale in Australia following investigations by Cummins (5) for the protection of veneers and plywood.

On the other hand, superficial treatments by spraying or dipping with certain oil and solvent preservatives have given promising results, and although these substances may be unsuitable and too expensive for application on a large scale to sawn lumber, they may prove of value for the protection of partly completed articles—such as dimension pieces, tennis racquet frames, willow clefts for cricket bats, &c., during storage on manufacturers' premises.

SUMMARY.

1. The object of this investigation was to determine the value of water-soluble salts and other preservatives for the prevention of damage by *Lyctus* Powder-post beetles in the sapwood of hardwoods.

2. The different types of preservatives and their suitability for the prevention of *Lyctus* attack are briefly discussed.

3. Materials, methods of treatment, and testing technique are described and the results of the tests are summarized in tabular form. The value of the preservatives and different methods of application tested are classified under the headings 'Effective' and 'Ineffective'.

4. It is shown that water-soluble preservatives are effective only when applied by an impregnation treatment.

5. Certain preservatives of the oil and solvent types are effective when applied by short-period dipping treatments.

ACKNOWLEDGEMENTS.

The work described in this paper was carried out as part of the programme of the Forest Products Research Board and is published by permission of the Department of Scientific and Industrial Research. The author wishes to express his gratitude to Dr. R. C. Fisher, Officer in charge of the Entomology Section, for his advice and helpful criticism, and particularly to Mr. E. C. Harris, Technical Assistant in the Entomology Section, who carried out most of the routine work of examining samples and recording results.

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NOTE ON A HEART ROT OF OAK TREES CAUSED BY *POLYPORUS FRONDOSUS* FR.

BY K. ST. G. CARTWRIGHT

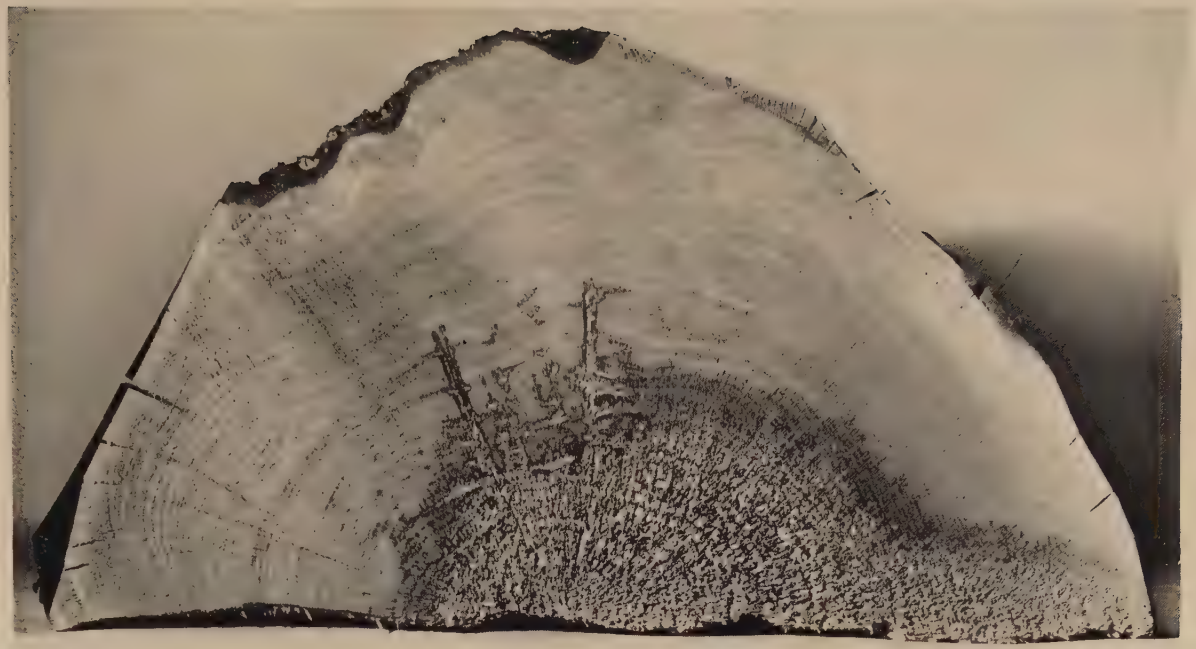
(Forest Products Research Laboratory)

IN the autumn of 1938 I visited the Forest of Dean in company with W. R. Day and T. R. Peace of the Imperial Forestry Institute, Oxford. At High Meadow, where a portion of woodland had been clear-felled and removal of the logs was taking place, the butt ends and stumps of two oak trees were found to be affected by a white rot which had originated in the heartwood. The type of rot was similar to that known as 'Partridge Wood', which is caused by *Stereum frustulosum*, but the white pockets of rot were less pronounced, and in an advanced stage decay was more of the 'stringy' type. In areas where decay was less advanced the outer margin of the decayed wood tended to be outlined by a 'water-soaked' reddish zone similar to that associated with decay by *Stereum spadiceum*, a fungus which causes a white pipe rot and is prevalent in the district. A photograph illustrating the advanced stage of the rot is reproduced in Plate I. Orange zone lines were present in some areas similar to those sometimes observed associated with decay by *Ganoderma applanatum* on beech. In one oak butt, the centre of which was partially hollowed out, fungus growths were observed. These growths had a somewhat hard crust, reddish-brown on the exterior; the interior was of a bright orange hue matching that of the zone lines observed in some portions of the decayed areas. Although it was not possible to carry out an analysis of the decay in the log, it was apparent that the rot column tapered upwards and would in all probability have affected the bole up to a height of about 6–8 feet from the ground. It was evident that infection had started from below and had spread upwards, and as no scars were present at the base of the tree the evidence pointed to infection having taken place through a root.

Samples both of the fungus and of the decayed wood were examined in the laboratory and cultures were taken from both. As it was thought possible that two fungi might be present, a number of cultures were taken both from the areas with orange zone lines and from ones showing no trace of them. In every case, except where mould contamination interfered with its growth, the same species of fungus developed. The medium used was a malt agar (Keppler's malt) at strengths of 2 per cent. and 5 per cent. The cultures developed the characteristic orange colour in patches, which was more marked when grown in the light than in the dark. In some instances fruit structures developed which though abnormal in shape produced a normal hymenial surface bearing basidio-spores. The fungus was identified by comparison with a standard culture as *Polyporus frondosus* Fr.

Polyporus frondosus, although not uncommon at the base of dead oak and

PLATE I



Advanced stage of rot in oak caused by *Polyporus frondosus* ($\times\frac{1}{3}$)

other frondose trees, has, as far as I am aware, not been reported in this country as the cause of serious heart rot in living oak trees. Hubert (3) describes briefly the characters of the rot, listing as hosts oak and chestnut, and includes a figure illustrating a late stage of decay in black oak. Boyce (2) states that the decay is usually connected with fire scars and quotes Long (4) as stating that *P. frondosus* causes a spongy butt rot of the heartwood of living oaks and American chestnuts. Bourdot and Galzin (1) consider that *P. intybaceus* Fr. may be only a variety, and treat the name as a synonym. *Polyporus giganteus* (Pers.) Fr., a closely allied species, has frequently been observed at the base of beech trees, as has *P. intybaceus*.

The fruiting tufts often arise a considerable distance from the base of the tree and generally their origin can be traced to the roots. In one instance the main root system of a large beech tree which had died the previous year could be traced out more or less by the position of the fruit bodies arising from it.

Brief descriptions of the appearance of the fungus in the wood and the main features by which cultures of the fungus can be identified are given below.

Description of Polyporus frondosus *Fr. in Sections of Oak Wood.*

There are no well-marked features by which *Polyporus frondosus* can readily be recognized from examination of the mycelium in wood sections. The hyaline hyphae are fine, being frequently only about 0·5 μ in diameter. Gumming is present in certain areas of the attacked wood and here the hyphae, which have occasional swellings on them, and in some cases are thick-walled, tend to become coloured by the gum. A few large hyphae have been seen in these areas, one measuring 6 μ in diameter. The hyphae bear simple clamps, though these are neither very frequent nor conspicuous. No secondary spores have been observed in the wood, although they may possibly be produced in the larger vessels and in the neighbourhood of a developing sporophore, as they are present in malt agar cultures. The hyphae are capable of boring directly through the walls of the wood elements, producing small bore-holes, but more frequently passage takes place through the pits. In an advanced stage of decay the wood when treated with phloro-glucin and HCl only shows a weak reaction, indicating that the lignified elements are attacked. As is general in the case of white rots, hydrolysis of the cellulose components also takes place.

Description of Cultures of Polyporus frondosus *Fr. grown on Malt Agar Medium.*

On both 2 per cent. and 5 per cent. malt agar medium mycelial growth of *Polyporus frondosus* is slow, being about 1·5 cm. and 4 cm. respectively in 3 weeks when not exposed to light. In the light, growth is retarded, there being no appreciable growth on 2 per cent., and only slight growth on 5 per cent. within the same period. Growth starts as an almost colourless adpressed mycelium, the diameter of individual hyphae being between 0·2 μ and 0·5 μ. Later, on 5 per cent., a white woolly to felty mat is produced, with a wide colourless growing zone of adpressed mycelium. Colour develops in patches later, this being more pronounced in cultures grown in the light. The colour range varies from *Maize Yellow*, *Light Cinnamon Buff*, to *Antimony*

Yellow.[1] The mature mat is moderately smooth, though small tufts are sometimes produced in less vigorously growing cultures. The texture of the mat is tough, resembling kid leather, and yellow drops of liquid are exuded from it.

Fruiting, though not of regular occurrence, is fairly frequent, the fruit bodies being formed usually towards the top end of the slant. They are of the *Poria* type, the hymenial surface being on the upper surface. The sporophore consists mainly of the pore surface which is made up of well-developed foliose plates with dentate margins, the pores being irregular and fairly wide in diameter. A normal hymenial surface is produced on which basidia are borne measuring up to 30 μ × 8 μ. Each basidium has four sterigmata, the length of these being about 9 μ. The basidiospores measure 5–6 μ × 3·5–4·5 μ, each spore having an obliquely placed apiculus (Fig. 1). The aerial mycelium averages from 3 μ to 5 μ in diameter, but a few hyphae measuring up to 8 μ have been observed. Some of the hyphae in the coloured patches contain a yellow oily material. The submerged hyphae average about 6 μ but vary from about 2·5 μ to 8 μ. Septation is regular and moderately frequent, and the larger hyphae are constructed at the point of septation, resembling in this respect those of *Coniophora cerebella*. The larger hyphae are thick-walled and some of them bear irregularly shaped swellings. Clamp connexions are present more especially on the smaller hyphae. Secondary spores are produced abundantly both on the aerial and on the submerged mycelium. They are both terminal and intercalary and size variation is great, 20 μ × 15 μ up to 50 μ and more. In Figs. 2 and 3 some of them are illustrated, together with hyphae taken both from the aerial and submerged mycelium. Crystals are present, but are not produced in abundance in actively growing cultures. The mycelium produces a strong oxidase reaction when tested with a gum and guaiacum mixture, this being characteristic of the group of white rot fungi which attack lignified tissue in addition to causing cellulose depletion.

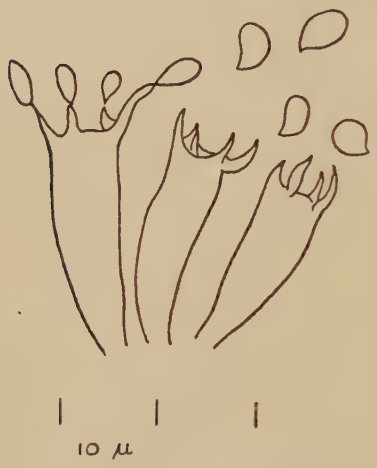


FIG. 1. Basidia and spores of *P. frondosus* on 2 per cent. Kepler's malt agar.

[1] Colours printed in italics are from Ridgway's *Color Standards and Color Nomenclature* (1922).

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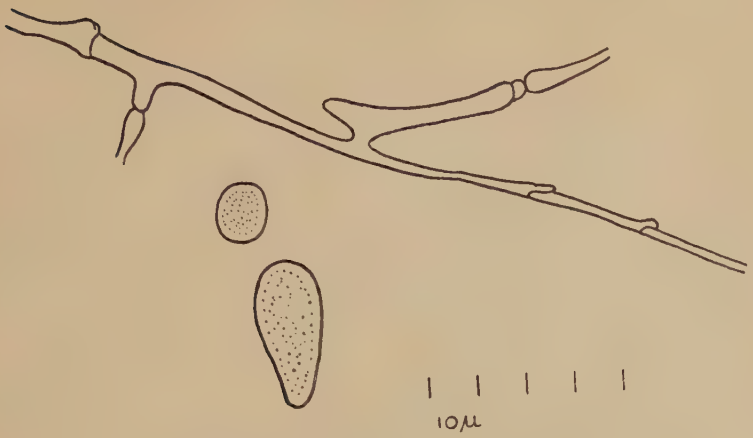

FIG. 2. Secondary spores and aerial mycelium of *P. frondosus* on 2 per cent. Kepler's malt agar.

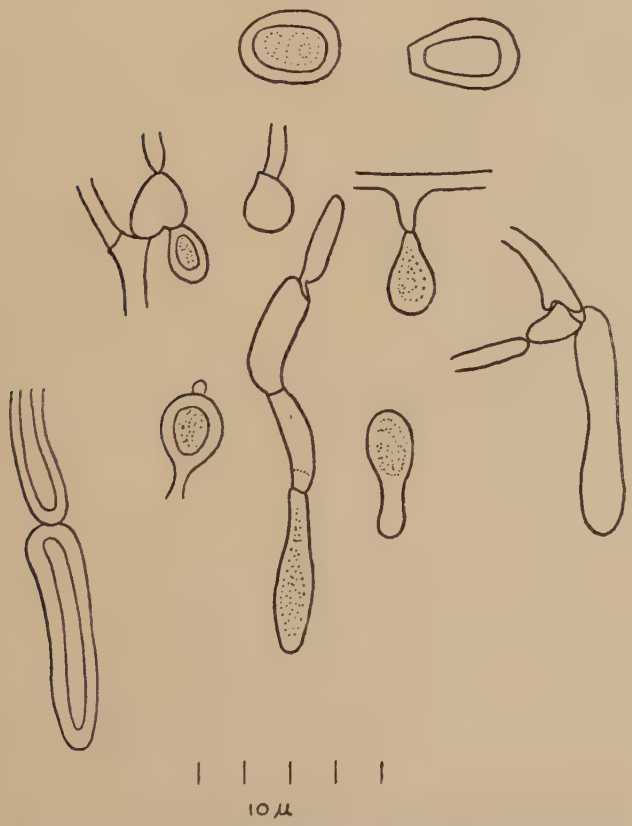

FIG. 3. Secondary spores and portion of thick-walled hypha from submerged mycelium on 2 per cent. Kepler's malt agar.

SOCIETY'S AND OTHER NEWS

Mr. William Herbert Lovegrove died on 25 January 1940, at Glastonbury, Somerset, where he was taken ill on a tour of duty as an Officer of the Timber Supply Branch of the Forestry Commission. At the outbreak of war, at the age of 72, he at once volunteered his services and his patriotic and gallant offer was gladly accepted.

Lovegrove was the fourth son of the late Charles Lovegrove of Petley's Down, Kent. He was educated at Dulwich College and, from 1886 to 1889, at the Royal Indian Engineering College at Coopers' Hill. He went to India in November 1889, having been appointed an Assistant Conservator of Forests in the Bengal Presidency. While in Bengal he served as Divisional Forest Officer in various divisions, and, on attaining the grade of Conservator, he was lent by the Government of India to Kashmir State as Conservator of Forests. He held this appointment for a number of years, and, while in Kashmir, did much valuable work towards the improvement of the extraction and marketing of their fine Deodar timber. Service in a Native State always calls for great tact in dealing with the Durbar and Maharaja, particularly in a large state like Kashmir, and in this respect Lovegrove was admirable.

In 1916, being in England on leave, Lovegrove took charge of the exploitation work in the New Forest Division of the War-time Timber Supply Department and remained there in charge until the end of the war. He finally retired from the Indian Forest Service in 1919, having completed 30 years' service, and, in the same year, was appointed Divisional Officer for South Wales under the newly formed Forestry Commission. He went to the Forest Research Laboratory at Princes Risborough in 1927 as Records Officer and Librarian, and there he inaugurated the system of records and catalogued the Library. He finally retired in 1933.

Lovegrove was one of the first members of our Society and one of the keenest. He was ever willing to do his utmost to further the Society's objects with which he was in complete sympathy. In India he had the reputation of being a sound, hard-working forest officer who could lead his men and get the best work out of them. His popularity, both in India and at home was universal and did but reflect his never failing kindliness and generosity of character. His lovable nature earned for him a wide circle of friends, all of whom grieve his loss.

W. L. T.

REVIEWS

The British Islands and their Vegetation. By A. G. Tansley. Cambridge University Press, 1939. Price 45*s*.

Review by the Editor

THIS volume of over 900 pages is not only much larger, but much more ambitious in scope, than its delightful predecessor, *Types of British Vegetation*, published in 1911. The task which Professor Tansley set himself almost justifies the use of that much abused adjective, colossal. He has succeeded in his aim to make the subject interesting, not only to the specialist but to a much wider public. Although he deals only with the ecology of natural and semi-natural communities, and not with that of artificially created plantations, this is a book which all foresters should read and study.

Part I deals with the environment of vegetation: physical features and geological history; climate, general and by regions; soil, including the distribution of soil types; and the biotic factor. This is an excellent outline of these subjects, and there are few points on which any criticism can be made. Perhaps because the author is concerned with the broader divisions of vegetation, there is no discussion of the influence of local topography, while microclimate is very lightly touched upon. Foresters consider these of great importance. In the description of the profile of a typical Brown Earth, a *gley* horizon is included. While this view is held by certain soil scientists, a Brown Earth may or may not have a *gley* horizon, and other soil types may have one, hence in the reviewer's opinion it should not be considered typical of a Brown Earth. In discussing frost, and in particular the May 1935 frost, no reference is made to the interesting data collected by Day.

In Part II there are interesting chapters on vegetation in prehistorical and historical times. In the chapter on Prehistory the author follows orthodox lines, but presents an interesting summary of the work on pollen analysis done in recent years and its interpretation. In discussing the forest history of Scotland, use is made of the late Mr. J. M. Murray's address to the Royal Scottish Forestry Society in 1935. This part concludes with a chapter on the distribution of the forms of vegetation.

Part III deals with the nature and classification of vegetation. Tansley's views can best be given in his own words: 'My exposition is based, of course, on what has been called the "dynamic" point of view, which is simply the explicit recognition that natural and semi-natural vegetation is constantly changing, that certain uniformities in the direction, methods, and causes of change can be detected, and that positions of relative equilibrium are reached in which the conditions and composition of the vegetation remain approximately constant for a longer or shorter time. Such a position of relative stability is here called a "climax", whether it represents a major community corresponding with a climatic region and primarily determined by climate, or a minor community determined by some other factor or factors.' This relative equilibrium is the condition in what he has termed 'a mature eco-system', and such dominated by distinctive life forms is a formation in Tansley's sense. The term association is applied to a major community with distinctive species, while he uses the other common terms in Clements' sense. Tansley's general thesis is not so intellectually logical as Clements', but it is more realistic and will be accepted by many, if not all, foresters. They should

not need to be warned that natural vegetation is not rigidly arranged according to any system of classification.

Part IV is devoted to 'woodlands', hence will be of major interest to foresters. Although professional foresters in this country have, in the main, to deal with artificial and not natural or semi-natural woodlands, they have used and are using the ecological approach in tackling their problems, hence they will study this section with care. Unfortunately, with the exception of Watt's work on Beechwoods, most of the work is descriptive and the forester has to study the correlations between site and vegetation. Nevertheless, there is much of interest and value to foresters in these chapters, including the results of Tansley's own observations on Scottish Pine and Birchwoods made while he was engaged on this book, and unpublished work on the Killarney Woods by a group of Cambridge ecologists.

Of the remaining parts, those of most direct importance to foresters are those that deal with grasslands, moss formation, heath formation, and coastal sand dune vegetation, and that because of their connexion with the afforestation of these communities. These will prove of considerable value, but the forester has to consider smaller units of vegetation than the ecologist, because minor changes may involve changes in choice of species and treatment.

As the book is of necessity based largely on published work, and ecological work has not as yet extended evenly over the whole field, the work is therefore to some extent unbalanced. Further, much of the ecological work, with certain notable exceptions, has primarily been descriptive, and the stage has not yet been reached when correlation and simplification is possible. The publication of this work should, however, act as a stimulus to further work and direct it along the most useful channels to secure these aims. For example, it is noted that there has been no important work on Scottish Heaths since that by the late Dr. W. G. Smith.

The book is beautifully illustrated, both by photographs and diagrams, and is well produced. The author is to be most heartily congratulated on a great piece of work well done, while the publishers also deserve a word of praise.

Thinning, Pruning and Management Studies on the Main Exotic Conifers grown in South Africa. By I. J. Craib, M.F., Ph.D. Science Bulletin No. 196, Department of Agriculture and Forestry, Union of South Africa, 1939. Price 1*s*.

Review by W. H. Guillebaud

ALTHOUGH the author labels this bulletin as 'studies' it forms in fact a logically constructed whole, each of the five parts of which it consists leading on to the next and forming part of a closely woven argument. The climax is reached, however, in Part IV, where the author sets out his original and somewhat drastic proposals for the modification of South African practice in the establishment and treatment of exotic conifers.

As is widely known, the bulk of afforestation in South Africa is carried out with four or five species of pines, namely, *Pinus insignis* (more properly *P. radiata*!), *P. patula*, *P. Pinaster*, *P. taeda*, and *P. caribaea*. Of these the three first-named are much the most important. *Pinus insignis* and *P. patula* have a rate of growth in South Africa which can only be described as phenomenal. For example, according to Craib's tables, Quality-Class II *P. insignis*, i.e. *P. insignis* of average growth (Craib dividing his tables

into only three quality classes), attains a mean height of 41 feet in 10 years and 71 feet in 20 years. Our fastest-growing conifer in Great Britain, Douglas fir Q.C. I, attains the same height in 16 years and 27 years respectively. *P. patula* grows almost as fast in South Africa as *P. insignis*, while the rate of growth on the better sites of *P. Pinaster*, the slowest growing of their major species, is approximately equivalent to that of Quality-Class I European larch in Great Britain. Those comparative data are mentioned in order to emphasize that growth conditions in South Africa lie largely outside our ken and that we must not overlook that fact when tempted to criticize Craib's unorthodox silvicultural theories.

In Part I of the bulletin Craib puts the South African house of forestry in order as regards data relating to current rates of growth and production. To be more precise, he has constructed yield tables for three species of pine, *P. insignis*, *P. patula*, *P. Pinaster*, based on a considerable number of measurements of individual trees, supported by a certain amount of sample plot data. Incidentally, Craib's method of constructing a single diameter height curve, based on individual trees, for all site classes is interesting. The author claims that the method was checked and verified by data from permanent sample plots. The most speculative part of these yield tables is the grade of thinning applied, but the tables purport to depict the course of production under current methods of thinning, and, bearing in mind the rate of growth, appear reasonable. The tables follow an orthodox course, the lower quality classes having a larger number of stems, age for age than Q.C. I.

In Part II Craib discusses the problem of pruning in relation to the course of development depicted in the tables given in Part I and comes to some interesting conclusions. Some of those relating to *P. insignis* are summarized briefly below:

(1) Even on the best sites (Q.C. I) pruning is not profitable above a maximum height of 22 feet.

(2) In order to prune to 22 feet for this site quality pruning must commence not later than the 6th year and be completed not later than the 9th year, and three pruning operations are involved.

(3) It is useless to prune unless a clean layer of at least 4 inches radius is put on over the whole central knotty core.

(4) Pruning in average Q.C. II sites may be carried to a maximum height of only 10 feet and no pruning at all is justified on Q.C. III sites.

(5) With the exception of the lowest branches the whole of the pruning involved is green pruning, i.e. whorls of living branches are removed.

In Part III Craib analyses anticipated yields and profitability under contemporary thinning practice as applied to the exotic species used in afforestation in South Africa. For this purpose he uses the somewhat speculative yield tables prepared in Part I of the bulletin, and a series of arbitrary values for trees of the range of sizes produced throughout the rotation. Cost of formation, a very important factor in the economics of afforestation, is dealt with rather gingerly, and Craib gives no data beyond an extreme figure of £20 per acre for planting *P. Pinaster* on strong soils in the Midland Conservancies, merely saying that over about 80 per cent. of the area afforested the expenditure is likely to exceed the revenue. The reason for this is, in the main, the fact that under the rotations contemplated in the yield tables, viz. 30 years for Q.C. I, 40 years for Q.C. II, and 50 years for Q.C. III, only 22 per cent. of the total volume produced are expected to be of sizes of 12 inches or over in diameter U.B. The smaller sizes which form the bulk of the yield will, according to Craib, be doubtfully marketable. The obvious solution of extending the rotation of the poorer quality class crops

sufficiently to enable the production of timber of an economic size is met by Craib by reference to his curves for age diameter at breast height given in Part I of the bulletin. These curves show that the lowest quality class of each species flattens off so rapidly that, in Craib's words (page 84), 'If the curves are extended according to their current trends, it is seen that a doubling of the rotation periods results in only minor increases in mean diameter.' This is a very crucial statement, and the reviewer would like to see fuller evidence than Craib has provided in his bulletin. The course of development in height, diameter, and form of crops of any species growing on poor sites cannot safely be predicted by any system of curves based in the main, as Craib's are, on a scatter of dots. The margin of error at the boundaries of a distribution is much greater than in the centre about the mean. We venture seriously to doubt whether in actual fact the third quality class age diameter at breast height curves of *P. Pinaster*, *P. insignis*, and *P. patula* would show the remarkably flat trends given them by Craib. *A fortiori*, we doubt the justification for basing a silvicultural policy on a hypothetical prolongation of curves to double the present rotation, i.e. for double the period which for any data at all exist.

However, Craib rejects on these grounds the extension of the rotation of the poorer quality classes and slower growing species and turns instead, in Part IV, to thinning as a means of increasing log diameter. He proposes, in brief, to give the trees on the poorer sites maximum growing space, controlling their branch development by means of live pruning. The method is perhaps best exemplified by reproducing Craib's proposed thinning schedule for *Pinus insignis*, in which we have included total heights from the curves given in Part I.

Quality-Class I. Planting spacing: 9 ft. × 9 ft.			Quality-Class II. 9 ft. × 9 ft.			Quality-Class III. 12 ft. × 12 ft.		
Age (yrs.)	*Height (ft.)*	*No. of stems per acre main crop.*	*Age (yrs.)*	*Height (ft.)*	*No. of stems per acre main crop.*	*Age (yrs.)*	*Height (ft.)*	*No. of stems per acre main crop.*
10	60	330	6	24	210	8	22	150
15	79	220	18	66	150	20	50	100
20	93	150	25	81	110	30	66	75
25	102	125	40	100	(110)	50	80	(75)
30	110	(125)	..	..	..	..	..	..

At the final age the mean diameter breast height is to be the same in all three quality classes, namely 17 inches.

The thinning schedule for Q.C. I is stated to correspond to current thinning methods. It is not actually unduly drastic, having regard to the light-demanding nature of the tree and the very rapid rate of growth. It is no heavier, height for height, than some of our own 'D' Grade thinnings of European larch in Great Britain. The two schedules for the lower quality classes, on the other hand, show a very different picture. In Q.C. II at the age of 6 years and height of 24 feet the number of stems is reduced to only 210 per acre. In Q.C. III the stocking is even more drastically reduced, and at 30 years of age the ground carries the final crop of 75 trees per acre with a mean height of 66 feet, the trees standing without additional thinning for a further period of 20 years to become mature at the age of 50 years.

Financially, the result of the new schedule, assuming it works out according to

plan, is to justify pruning to a height of 22 feet in each Quality-Class and to increase greatly the economic returns from afforestation in South Africa.

Now Craib's whole thesis, as developed in this fourth part of his bulletin, is so closely and ably argued and supported by so much tabular matter as to make it extraordinarily difficult to criticize fairly in the space of an ordinary review, but we must content ourselves with expressing some of the questions which irresistibly rose to mind when reading this work:

(1) A great part of the theory that the growth on the lower quality-class sites can be stimulated by more growing space rests on Craib's earlier work on Wattles and on a series of thinning plots of *Pinus patula* at Weza in Natal. Is not this rather a slender foundation for such an imposing superstructure?

From the data given in the bulletin, the Weza Plots appear to be about I/II Quality-Class, i.e. an average to good site, and so of somewhat questionable validity when used as a basis for revolutionary methods to be applied to low-quality sites for the species in question.

(2) Will such a drastic reduction in the number of stems on the poorer sites leave sufficient stems for final selection? Accidents happen and such a thinning schedule seems dangerously like putting all the eggs in too small a number of baskets.

(3) The isolation of the trees at such an early stage of development necessitates, of course, live pruning. It is true that so far there is no evidence against such pruning in the case of the species in question, but is there not a risk that technical difficulties may arise, e.g. disease, resin occlusion, &c.?

(4) What is going to be the effect of the isolation-cum-pruning procedure upon the form of the trees? Is there any evidence that the trees, if they do respond to the increased growing space, will not be excessively tapering?

(5) Increased growth as a response to increased growing space implies greater average width of ring. Craib quotes Turnbull's work as evidence that strength is not affected by rate of growth, the production of summer wood being consistently proportional to the production of spring wood, irrespective of the growth-rate of the tree investigated. This is an important conclusion, if fully verified, but there are other properties besides strength which may be affected by increasing ring width beyond a certain point, e.g. shrinkage on drying, wood-working properties such as planing, morticing, &c. Have these also been taken into account?

(6) The very heavy early thinning prescribed for the second, and still more the third quality-class crops, will inevitably result in a great development of grass and other vegetation. It is true that the Weza plots show that, on that particular site, growth was so vigorous after the thinning that canopy was quickly re-established and the vegetation killed out. Is it safe to conclude from this single set of I/II Quality-Class plots that plantations on greatly inferior sites will react in the same very favourable manner? Is it not more likely that on many of the poorer sites the natural vegetation will get the upper hand and stagnation in the growth of the trees set in?

(7) When we take, as Craib has done, the full range of growth of a given species, and divide that range into three quality-classes, the third quality-class will usually contain a much greater variety of sites than the other two. The reason for this is that climatic factors often reinforce, but occasionally mitigate, the effects of adverse soil conditions; thus a given crop may owe its poor growth either to unfavourable soil conditions or to an unfavourable climate or to some combination of the two. Reaction of the trees to a given method of treatment will vary with the nature of the limiting factor and any large departure from accepted silvicultural methods must be more

hazardous in the case of third-quality sites than in the case of those of average or good quality.

In voicing these doubts and questionings, the reviewer does not wish to be considered as purely critical in his attitude to Dr. Craib's proposals. He was himself fortunate enough to visit some years ago the Weza Plots in company with Dr. Craib and was greatly impressed with the plots and with the originality of Dr. Craib's outlook. A further strong ground for caution in criticism is the outstanding fact that Dr. Craib's proposals were accepted in principle by the South African Forestry Service at a Conference of Senior Forest Officers held in Pretoria in March 1938. The executive forest officer is not as a rule very ready to swallow the recommendations of his research colleagues, but we have here a case of an entire service being willing to make important modifications in practice on the advice of the Research Department, a fact which certainly deserves to be put on record.

In the last part of the bulletin Craib makes definite recommendations regarding the treatment of the existing coniferous stands in the Union. He concludes that owing to risk from windfall and for other reasons it is not desirable to make any radical departure from standard thinning methods in the older plantations. It is only in the very young plantations that the new technique can be safely applied.

In conclusion, we wish to congratulate Dr. Craib on a very able piece of work as well as on the gratifying acceptance it has found with his executive colleagues. If this review induces the reader to study and digest the original bulletin, the main object of the reviewer will have been served.

The Growth and Nutrition of White pine (*Pinus strobus* L.) *Seedlings in Cultures with varying Nitrogen, Phosphorus, Potassium, and Calcium.* By H. L. Mitchell. The Black Rock Forest Bulletin No. 9, New York, 1939.

Review by A. B. Stewart

THIS bulletin deals primarily with the growth and nutrition of White pine seedlings grown in sand-pot cultures, in which the four major nutrients, nitrogen, phosphorus, potassium, and calcium, have all been varied in individual series; but there is in addition a most useful discussion on general aspects of nursery manuring, which still rests too often on an inefficient and haphazard basis. Carefully conducted field experiments can be of direct value in determining the treatment to be given to a particular nursery, but on account of variations in soil conditions and other growth factors, it is unsafe, if not impossible, to generalize on nursery manuring from the results of individual experiments. In this bulletin the view is upheld that pot experiments followed and confirmed rather than preceded by field experiments is the procedure likely to yield the most useful fundamental information on the nutrient requirements of forest tree species.

In the experiments described, seedlings were allowed to grow for 108 days, after which they were harvested, washed, examined microscopically, subjected to root/shoot determinations, dried, ground, and analysed for major nutrient substances. Seed size and source, temperature, moisture, aeration, and solar radiation, as well as actual nutrient supply, are all factors of importance in seedling growth, and in these experiments the aim was to keep constant all growth factors except the particular one which was being studied. It is emphasized, for instance, that seed weight has an important influence on the early cumulative dry weight of several species of pine and that the

distribution of weights in an average sample of pine seeds can account for variations of the order of ±35 per cent. in the mean weight of 1-year seedlings.

It has been found that nutrient uptake and seedling growth vary with external nutrient supply and that the results can be fitted to logarithmic yield curves on the lines proposed by Mitscherlich. Seedling dry weight is shown to be proportional to individual variations in the external supplies of each of the major nutrients, and for each element there is a definite optimum concentration. With White pine, for example, the optimum supplies for the different elements were, in parts per million: nitrogen 300, phosphorus 350, potassium 150, and calcium 200. Amongst some of the other more interesting findings the following may be mentioned. The response of seedlings is greater to individual increases in the supply of nitrogen and particularly potassium and calcium than to equal increments of phosphorus. The range of supplies through which the yield approaches its maximum is much more limited for potassium than for phosphorus and calcium and to a lesser extent nitrogen. The root/shoot ratio varies inversely with nitrogen supply and increases up to a definite limit, after which it decreases, with increases in the supplies of each of the other three nutrients.

Chemical analyses of the seedlings showed a high correlation between nutrient uptake and amount of nutrient supplied and the internal nutrient concentration is considered to be a diagnostic factor of considerable importance. In the young seedling the internal nutrient concentration is low; as the seedling grows the supplies necessary will be greater, and this leads to the question of time of application of a fertilizer. In general terms the conclusion is that it is advisable to avoid high or toxic internal nutrient concentrations early in the season. At the Black Rock Forest Nursery it is found that fertilizer applications based on the results of periodic chemical analyses of the seedlings are more effective than nutrient supplements made in the ordinary way. In considering the time of application of a fertilizer account must, of course, be taken of the physical properties of the soil. In a light soil with a low capacity for binding or adsorbing nutrients there may be a risk of the soluble nutrient concentration being too high early in the season, but in a heavier well-buffered soil with a high adsorbing capacity the risk should not be great.

Nitrogen Nutrition and Growth of Certain Deciduous Trees of North-eastern United States. By H. L. Mitchell and R. F. Chandler, jr. Black Rock Forest Bulletin No. 11, 1939.

Review by A. Muir

THE methods of leaf analysis have not been used to any great extent by soil-workers in the evaluation of the nutrient requirements of forest trees. It is shown in this bulletin that there exists a definite relationship between the nutrient content of the soil, the leaf content of the element in question, and the annual radial increment of the tree species. Although some data are given for experiments with phosphorus and potassium, the main results reported are concerned with nitrogen. A series of plots were established in different parts of the North-eastern States; at each place the set consisting of a control and three others which received increasing supplements of nitrogen. The fertilizer used was a 1 : 1 mixture of commercial nitrate of soda and sulphate of ammonia. Near the end of the growing season, i.e. when the leaves were physiologically mature, leaf samples were taken for chemical analysis from the dominant and codominant trees on each plot. An attempt was made to have samples from at least ten trees, but this was not always possible.

Both the growth of the trees and the nitrogen-content of the leaves increased with increasing supplements of fertilizer, and it was found that the relationship could be expressed algebraically by the Mitscherlich formula. On the basis of growth response the range of nitrogen supply could be divided into regions: the region of minima, the working region, the optimum region, and the region of tension in which little or no change in radial growth takes place. The curves of average relationship between the nitrogen supply and the radial increment of nearly mature deciduous trees are essentially the same as those which express the dry weight increase of 1-year-old coniferous seedlings grown in nutrient sand-cultures of varying nitrogen concentrations as described in the previous review. The toxic region found in connexion with the growth of seedlings did not appear in the present experiment even on the most fertile soils.

The various species were found to differ considerably in their nitrogen requirements. For instance, red, white, and chestnut oaks, aspen, and red maple all showed good growth on soils that were relatively nitrogen deficient and reached their maximum radial increment at lower levels of nitrogen supply than any of the other trees. Among the nitrogen-demanding species were white ash, yellow poplar, and basswood, which were infrequent or absent from the poorer sites.

A relation similar to that between nitrogen supply and growth increase was also found to exist between the internal (or leaf) nitrogen content and growth increase and the species arranged in the same groups.

Data for similar experiments with potassium and phosphorus are as yet meagre. What are available show that the internal concentration of these elements increases when dressings are given, but tree measurements on potash fertilized plots suggest that the particular soil was well supplied with that nutrient since no growth response was observed.

Although the methods of leaf analysis are only comparative, it appears that they provide a much more satisfactory basis on which to erect a scale of soil fertility than the analysis of the soil itself. It is certainly much simpler and obviously takes into account the effect of biological factors that are completely ignored in most soil analysis. The authors show how by means of their technique the comparison and co-ordination of data from a large number of different sites can be made a relatively simple matter. It is emphasized that the chemical aspects of the site may be more important than has been hitherto realized on account of the dearth of data on forest tree nutrition.

Further Notes on the Ecology and Control of Pine Beetles in Great Britain. By H. S. Hanson. *Bulletin of Entomological Research*, vol. xxx, part 4, pp. 483–536. 3 Plates.

Review by R. N. Chrystal

THE author of this paper has already published one paper on the ecology and control of the pine beetles in Great Britain, which appeared in the same journal in 1937. His present paper is a detailed account of the continuation of the experiments and observations described in his previous work, together with other new work. Mr. Hanson's investigations, which were commenced in 1933, have been continued without interruption up to the present time, and they embrace not only detailed experiments in the New Forest carried out over a period of years, but also extensions of these experiments to many parts of Great Britain, and many varieties of forest conditions. The author's practical knowledge of forestry in all its branches, serving as it does as a solid basis for his entomological studies, should be a strong recommendation to all foresters

to read and ponder over what he has to tell them about the pine beetles and their control.

In the first part of the paper the author discusses the results of his studies on the factors governing the interaction of the injurious pine-beetles with their parasites and predators, and the ecological factors associated with the host-tree. He is concerned to show to the forester how best to conduct his thinnings in pine plantations, and, in particular, just exactly how much waste material can be left lying on the ground after thinning without danger to the standing crop. These sections of the paper are directly associated with discussions on the results of thinning at different seasons, the use of billet and trap-stems, and the great importance of wind-fallen and snow-broken trees in providing facilities for the increase of such destructive bark-beetles as *Myelophilus minor* in the north-east of Scotland.

The author then proceeds to review the results of the comprehensive bark-beetle survey which he has carried out over all parts of Great Britain, and the reader should particularly note the results of his studies on their parasites and predators, with which he deals on pages 505–10. He also has something to say about the imported species of bark-beetles such as *Polygraphus polygraphus* L., *Ips sexdentatus* Boern., &c., which have found their way into the country at one time or another. He discusses, on pages 511–15, their present status and the possibility of their extending their range of activity.

In the last section of the paper, the rise and development of bark-beetle populations is discussed, the author illustrating his remarks by reference to his own work in Great Britain, and the work of continental observers such as Schedl (1937) and Butovitoch and Trägårdh (1935–8). These discussions on the causes leading to the fluctuations in the numbers of the bark-beetle populations are followed by a brief consideration of suggested control measures against the attacks of *Myelophilus*, the *Hylastes* beetles, and the weevils *Hylobius* and *Pissodes*, in crops of different ages.

This question of the menace to our coniferous crops from the attacks of bark-beetles and weevils is a very important one, especially at this time when so much war-time felling is going on in all parts of Great Britain. The forester has, in this paper, an extremely well documented account of the problem and of the solutions advanced to solve it. He will do well to study the author's results with care, and better to put some of his recommendations into immediate practice.

Timber: Its Properties, Pests and Preservation. By F. Y. Henderson, D.Sc., D.I.C., F.L.S. Pp. 185 and 59 figures. Crosby Lockwood & Son, Ltd., London, 1939. 9*s.* 6*d.* net.

Review by E. W. J. Phillips

THE author has aimed at producing a book dealing 'simply but adequately with the different aspects of timber, so that the reader may gain a general grounding, enough for everyday purposes and capable of development in one direction or another if it so desired'. It is written by a scientist accustomed for the past 10 years to introducing engineering and building students to the fundamentals of timber technology. Accordingly, due appreciation is given to the results of the vast amount of timber research carried out in recent times in so far as they affect the various classes of timber user.

The book commences with a consideration of tree growth and the microscopic structure of Scots pine and English oak exemplifying the two classes of commercial

timber. Having established an adequate background in the short space of 25 pages, the author goes on to the conversion of the log and the physical and mechanical properties of wood. Factors determining external appearance, density, shrinkage, and other moisture relations are dealt with and also the significance of the various strength properties and reasons for their variation, methods of testing, and the application of the results. The next three chapters deal largely with the negative aspect of timber: knots and other natural defects; the action of staining and wood-rotting fungi, including instructions for detecting fungal attack and a useful table for diagnosis and remedial treatment; the various types of insect and other animal damage, again including a table to aid in recognition of the chief pests of timber. This leads on to the importance of proper seasoning and preservative treatment. A short account is given of the principles governing natural and artificial seasoning, while methods of protection against fungi, insects, and fire, being of more general interest, are dealt with at some length. The remainder of the book is occupied with general notes on the character and utilization of the principal commercial timbers, an introduction to timber identification (including a short key to the commoner British woods, based on readily observed anatomical features), methods of steam bending, veneers, and plywood and, as an appendix, a method of examining wood microscopically for the presence of fungi. A short bibliography of selected references suggested for further study is included and also an adequate index. The text is supplemented by numerous excellent photographs and drawings.

It is, perhaps, a pity that in a publication reasonably assured of a wide circulation amongst the rising generation of timber users that the opportunity has not been taken to indicate the efforts which have been made in recent years towards standardization of the nomenclature of timbers and of terms applicable to timber. The most up-to-date practice has not been very closely followed here in these respects, and in the chapter on grain and texture an initial condemnation of the loose manner in which these terms are customarily employed and rigid adherence to their stricter meaning would have permitted a simpler treatment. But these are minor criticisms and the book may be wholeheartedly recommended both to timbermen and laymen.

Publications of this character, written for a wide audience, are commonly guilty of frequent omission or some halving of the truth. Dr. Henderson avoids these faults, yet rarely betrays any cramping of style in consequence. The style is terse but interesting, and it is worthy of note that so much fact can be presented in no more than 185 very readable pages.

Fremdländische Wald- und Parkbäume (Exotic Trees for the Forest and Park). By Dr. Carl Alwen Schenck. (In three volumes.) Paul Parey, Berlin, 1939.

Review by W. H. Guillebaud

THE author, Dr. Schenck, of this truly monumental work is probably well known, by repute at least, to many British foresters. Schenck's professional career, spent for the most part in the United States, and his extensive travels in India and other parts of the world, have endowed him with an unusually cosmopolitan outlook for a German, and also fitted him to a quite unique degree for the task which he has successfully completed in three large volumes.

In his choice of title, Schenck deliberately challenges comparison with the classic book on the same subject and with the same title written many years ago by Henrick Mayr. During the interval which has elapsed since the publication of Mayr's *Fremdländische Wald- und Parkbäume* an immense amount of additional information has

become available, not only as regards the behaviour of exotic trees in European countries, but also, and this is at least as important, about the conditions under which most of these species are growing in their native countries. Small wonder, then, that Schenck requires three vast tomes and the utmost compression of text to deal with a subject which Mayr covered tolerably easily in one modest volume.

Of the three volumes, the second and third are descriptive and deal respectively with the conifers and hardwoods, the first volume is largely tabular, but the latter part contains nearly 500, mostly magnificent, photographs of trees in their natural surroundings. A more detailed account of these volumes will now be given.

In his Introduction Schenck states that his book stands or falls with the thesis that a race of an exotic species when transplanted to a different region thrives best in that region in which there is the closest parallelism between the new climate and the climate of origin. The climate, according to Schenck, is best defined in terms of the average monthly temperature and rainfall, together with data (when available) as to extreme temperatures, more particularly winter minima. Accordingly, in his first volume Schenck has collected a great mass of climatological data together, thereby earning possibly the gratitude of meteorologists as well as foresters. The arrangement of the data is by Climatic Regions (*Klimasektionen*). Thus North America, excluding Mexico, is divided into 120 climatic regions, a further 22 regions suffice to cover the greater part of Asia, 16 cover Europe, apart from Germany, to which no fewer than 24 climatic regions are allotted. Schenck does not deal with any trees from the tropics or from south of the equator, an omission which is to be regretted when we consider that such trees as the Chilean and New Zealand species of *Nothofagus* are left undescribed.

For each of these climatic regions Schenck gives a table setting out the mean monthly temperature in degrees centigrade and rainfall in millimetres for a number of meteorological stations distributed as far as possible over the range of latitude and elevation comprised in the region. The stations are given in alphabetical order, a convenient arrangement in some ways, although if they were placed in order of elevation or even of latitude it would be easier to grasp the climatic character of the region generally.

In the more important regions, e.g. west Oregon, the monthly mean temperature and rainfall data for 20 or more stations are given, ranging in elevation from sea-level to 4,000 feet. The tables are succeeded by a series of paragraphs dealing respectively with land utilization, observations on the climate with notes on average and absolute maximum and minimum temperatures, and a general description of the composition of the forests of the four sub-sections into which the region is divided. Schenck's intimate personal knowledge of many parts of the United States is apparent in the breezy style of the descriptive sections which add no little to the interest of an otherwise rather tedious mass of data.

The photographs which fill the remainder of this volume must represent the cream of the unrivalled collection of photographs amassed by the United States Forest Service. Those depicting the old natural stands of such species as *Tsuga heterophylla*, *Pinus ponderosa*, Douglas fir, the Sequoias, &c., are particularly impressive. The remaining photographs of Indian, Japanese, and Siberian forests are less successful though interesting by way of contrast to the American stands.

The two large volumes which complete the trilogy deal respectively with the conifers and broad-leaved trees which can be grown either as forest trees or for ornamental purposes in Germany. Each volume contains over 600 pages of print and 171 coniferous and 290 broad-leaved species are described in greater or less detail.

In his nomenclature Schenck has followed the American botanist, Rehder, with the result that the majority of the specific names are those with which we have long been familiar.

As an illustration of the method followed by Schenck in discussing the more important genera and species, we may take his description of the North-West American conifer *Abies grandis*. The section devoted to *Abies* starts with a survey of the genus, the object of which is to facilitate the identification of any given species. Schenck makes no attempt to construct formal botanical keys, but instead he gives a series of tables in which the species are grouped according to certain characters. In the case of the *Abies* these are as follows: (1) Country of origin. (2) Resinous character of the buds. (3) Occurrence of pubescence on the shoots. (4) Position of the resin canals in the needles of shaded twigs. (5) Position of schlerenchyma in the needles of shaded twigs. (6) Form of the needle apices on shaded twigs. (7) Presence of stomata on the upper side of shaded twigs. (8) Prominence of the cone scales. With the aid of these tables the identification of any given species is usually a simple matter. In many ways such tables are more satisfactory for purposes of identification than formal keys.

On turning to the species *Abies grandis*, we find first a list of synonyms, followed by a botanical description occupying the best part of a page, to which is appended some useful notes on characters distinguishing *Abies grandis* from closely allied species; then comes a short note on cultural varieties followed by a section on the distribution of the tree in North America with reference to the respective climatic sections, the meteorological data for which are given in volume i of Schenck's work. The author then refers to the general behaviour of the rate of growth of the species in Europe, most space naturally being given to Germany. We observe in passing that except as specimen trees very little use appears to have been made of this species in Germany. Section V is headed 'Silviculture' and describes the behaviour of the species in its native habitat. It is in these silvicultural descriptions that Schenck's almost unrivalled knowledge of American forests stands himself and the reader in good stead. The next section deals with protection, e.g. liability to disease, both in its native habitat and in Europe, behaviour as regards frost, drought, &c. Section VII, headed 'Utilization', is one to which the British reader will often be glad to turn; he will find more information on timber uses than can readily be obtained elsewhere. Schenck's remarks on the timber of *Abies grandis* are not very favourable; in Canada and America it is generally regarded as worthless except for pulp, and even as pulp it is inferior to spruce. Schenck ends his observations on *Abies grandis* with a section headed 'Suitability for Cultivation' (*Anbauwürdigkeit*) in which he says that the value of the species in the future for German forestry and arboriculture must depend largely on its resistance to attack by the Silver fir chermes and on its liability to damage by game. He recommends the extensive formation of trial plantations.

So much then for the general layout of the descriptive volumes of the work. The amount of space given to any particular species varies naturally with its importance. A minor species such as *Abies holophylla* gets about 1 to 1½ pages, *Abies grandis* over 7 pages, while no fewer than 68 pages are devoted to Douglas fir.

There is a wealth of personal knowledge and experience in Schenck's description of the major American forest trees, and no British forester could read these and fail to profit from the experience. Schenck's style is racy, his judgement often unconventional and sometimes startling, but always stimulating and instructive. The average German text-book has a reputation for profundity and dullness which is often well deserved, but the present work cannot be classed with such monuments of heavy learning.

There is only space in a short review to note a few of the points of interest. In discussing the Black walnut *Juglans nigra*, Schenck summarizes in a long table the results of dozens of German experiments with this species; out of every ten plantations nine have failed, an experience which tallies closely with that in this country. More remarkable, however, is the statement that while acting as a forest officer for 14 years in the natural home of the Black walnut in the Appalachians, Schenck was unable to secure any successful regeneration. All attempts to regenerate by direct sowing or planting were equally unsuccessful, even when carried out in remnant stands of the old *Juglans nigra* forest. This provides a clear indication of the very delicate balance of nature necessary to secure the survival of certain tree species. Once this balance has been upset by the clumsy hands of man it is often impossible to restore it to its original efficiency.

Schenck has some interesting observations to make on the American red oak, *Quercus borealis* (*rubra*). From his personal knowledge of the timber he challenges the common statement that this is inferior, and maintains that when slow grown it provides an exceptionally good furniture wood. He says that in America red oak is largely used for railway sleepers, the heartwood absorbing creosote as well as the sapwood. From the silvicultural point of view red oak is a useful species because it thrives on poorer and especially drier soils than the common oak.

Schenck has evidently an enthusiasm for the tulip tree, *Liriodendron tulipifera*, which he describes as the aristocrat of the American hardwood forests, demanding, but also responding to, the best possible conditions of soil and climate. It is tender to early and late frosts but not more so than our common ash. Schenck recommends its introduction in coppice-with-standard forests on good soils and in carrs and other moist woods liable to periodic flooding.

Schenck has little to say on the subject of mycorrhiza the importance of which, thanks largely to the work of Dr. M. C. Rayner in this country, is now generally recognized. The climatic formula on which Schenck lays so much weight may in actual fact play a lesser, and biological factors such as mycorrhiza a greater, part in the success of exotic species than he is apparently ready to admit.

Whatever the shortcomings of the work may be, it is a great undertaking and contains a mine of information both for the forester and the arboriculturist.

NOTICES

Silviculture of the Trees of Trinidad and Tobago. By R. C. Marshall. Oxford University Press, 1939. Price 21*s.*

THIS book is the result of the author's 11 years' work in this colony, and is a monument to his energy and ability.

In the Introduction there is a brief but interesting description of the topography, geology and soils, climate and vegetation types, and the correlation of the latter with climate. Data from enumeration surveys are given for the principal forest types. The latter include five types of tropical rain forest, three types of tropical semi-deciduous forest, and a number of edaphic climaxes including mangrove. The author's views on the silviculture of tropical high forest, and the role of the lower canopy strata are of interest.

The principal part of the book is devoted to the description of the species of trees arranged in families. The information given is as follows: botanical and common name, general description of the tree, distribution and habitat, botanical description, germination, seedling, silvicultural characteristics, natural regeneration, artificial regeneration, statistical and utilization. Most attention is given to the important trees economically, for example, the Cedar *Cedrela mexicana* is dealt with in detail.

The book is beautifully illustrated by sixteen plates and many line drawings and diagrams. It is a model of what such a book should be, and contains much of interest to the forest officer wherever he may be located. The publishers are to be congratulated on the production.

The Management of Farm Woodlands. By Cedric H. Guise. McGraw-Hill Publishing Co., Ltd.: London, 1939. Price 20*s.*

IT is stated in the Preface that the book is designed primarily to meet the needs of students in agricultural colleges where instruction on farm forestry is given. For such it is an admirable text-book, but it is probably too 'meaty' for the average practising farmer. While it is written for American needs, much of it is of equal use in this or any other country with a temperate climate.

Forestry on farm lands is of much greater importance in all countries than is generally realized, but one is surprised to read that in the United States farm woodlands capable of producing timber of commercial quality occupy approximately one-fourth of the total area of commercial forest lands and amount to 127 million acres.

This book is in essence an outline of all phases of forestry work. Chapters I and II deal more specifically with farm woodlands, Chapter III with the structure and physiology of trees, Chapter IV with the ecology of woodlands, and so on through methods of determining volumes of trees and stands, forest planting and utilization to simple forest management. It is written from a more practical point of view than some recent 'Outlines', and can be recommended to all who require such a book.

A Handbook of Home-grown Timbers (Second Edition), 1939. Price 2*s.*
A Handbook of Empire Timbers, 1939. H.M. Stationery Office, London. Price 3*s.* 6*d.*

BOTH these books are planned on the same lines. Each opens with a chapter discussing the properties of timber and then follows a section on each species dealt

with. The latter gives a short description of the tree, a general description of the timber, seasoning properties, wood-bending properties, mechanical properties (details in an appendix), natural durability, insect attack, preservative treatment, working qualities, uses, and available supplies. In addition to an appendix dealing with mechanical properties, there is one giving kiln schedules, and another giving specifications for the teeth of circular saws. The volume on home-grown timbers deals with 26 hardwoods and 9 softwoods, and that on Empire timbers with 79 hardwoods and 17 softwoods.

These two volumes, published at a modest price, should be in the hand of everyone who is engaged on the production and use of timber.

Timber in War-time. By Reginald Davey. The Estates Gazette, Ltd., 1940 Price 3*s.* 3*d.*

THIS little book, except, with some reservation, the chapter on measurement of timber, can be recommended to all who are engaged in the sale or conversion of timber during present conditions, because it brings together useful information in a small bulk. The chapters deal with timber and control, disposal, measurement, prices and costings, and restocking felled areas. There are appendixes on Acts and Regulations, controlled prices, crop statistics—a curious compilation, timber tables and quarter girth and diameter equivalents.

The author's experience of forestry appears to be limited to the south of England, and in some respects does not appear to be very profound. This is indicated especially in the chapter on measurement of timber. The larch wood given as an example on page 24 appears to have a remarkably high form-factor, and the author's remarks on the use of basal areas is a little naïve. A much simpler method of estimating the volume of trees in different quarter-girth classes, for example for price differentiation, is to determine the percentage distribution of basal area amongst the classes and to apply these percentages to the total volume. The method described for this purpose on page 25 is a curious one. The sample plot method described is scarcely adequate for sale purposes, and does not conform with modern practice.

Report of the Forest Products Research Board for the year 1938. H.M. Stationery Office, London. Price 1*s.* 6*d.*

THE Report, as usual, briefly describes the various activities of the Board. It is regrettable, however, that its publication is so late. Although the Chairman's introduction is dated June 1939 the Report was not published until January 1940.

It is of interest to note that research is contemplated on composite wood, with the view of building up knowledge on this form of wood comparable to that already available for solid wood. This is a wise decision.

Perhaps somewhat belatedly, attention is now being directed to an increasing extent to the application of statistical methods in planning experiments, and interesting work in this connexion is described.

Attention continues to be directed to the moisture-content of wood, both in its theoretical and practical aspects, and a considerable part of the Report is devoted to this subject. Other subjects of practical importance dealt with are woodcutting research and the action of fire-proofing compounds. Charcoal manufacture in portable kilns is

now a matter of importance, and improvements in design have resulted in a decrease in volatile matter and improvement in quality.

In the entomological section, reference is made to the work on starch depletion in connexion with *Lyctus* control, and further work on the life-history of the death-watch beetle.

Of immediate interest to foresters in this country are brief references to the suitability of home-grown *Thuya* for poles and the quality of home-grown Sitka spruce. As regards the former the strength and density is appreciably lower than recorded for the same species in Canada, and less than that for Baltic redwood. The observations on Sitka spruce are promising but vague.

The increased number of inquiries from trade sources indicate that the work of the Forest Products Research Laboratory is being appreciated more and more.

Imperial Forestry Institute, University of Oxford. Fifteenth Annual Report, 1938–9.

THE Report opens with a tribute to the worth and work of the late Professor Troup. The activities of the different departments are briefly described. Some points of interest are references to work on *Adelopus gaumannii*, the cause of forking of ash, and 'chafer' beetles.

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